APPENDIX V

Pressure Surge Analysis

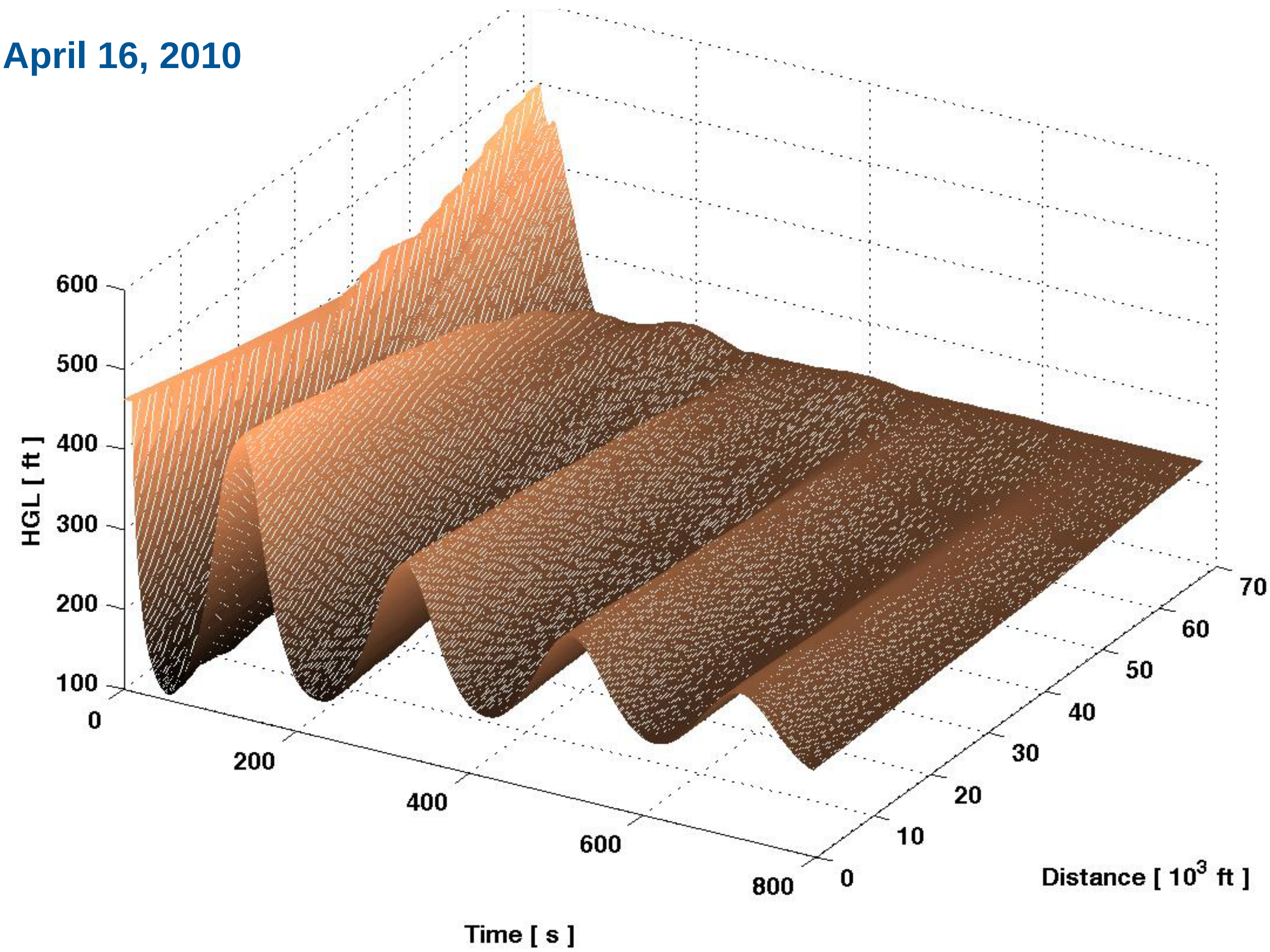
Prepared by Northwest Hydraulic Consultants,

April 2010

Huntington Beach Seawater Desalination Plant Pressure Surge Analysis

Poseidon Resources Corporation
Huntington Beach, CA

April 16, 2010



northwest hydraulic consultants

water resource specialists

Huntington Beach Seawater Desalination Plant
Pressure Surge Analysis
Poseidon Resources Corporation

Prepared for:
Poseidon Resources Corporation
17011 Beach Blvd., Suite 900
Huntington Beach, CA 92647

REGISTERED PROFESSIONAL ENGINEER
DAVID H. AXWORTHY
No. 62205
Exp: 9/30/2011
CIVIL
STATE OF CALIFORNIA

Prepared by:
Northwest Hydraulic Consultants, Inc.
80 South Lake Avenue, Suite 800
Pasadena, CA 91101
Contact: David H. Axworthy, Ph.D., P.E.
Tel.: (626) 440-0080

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This report was prepared by the following individuals:

David H. Axworthy, Ph.D., P.E. (CA), License No.: 62205, Associate,
Nami Tanaka, M.S., P.E. (CA), License No.: 75711, Engineer

This report was reviewed by the following individuals:

Edward E. Wallace, M.S., P.E. (CA), License No.: 32301, Principal in Charge

DISCLAIMER

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1.0 Executive Summary

A pressure surge analysis has been completed for the Poseidon Resources Corporation's (PRC) proposed 50 MGD Huntington Beach Seawater Desalination Plant and the associated product water delivery system. Northwest Hydraulic Consultants (NHC) developed a hydraulic transients computer model of the product water delivery system and performed pump power failure and startup analyses for the operation of three (3) proposed booster pump stations and one existing booster pump station under several operating scenarios. This report presents the findings from the pressure surge analysis and recommendations for surge control that will protect the integrity of the product water delivery system. The predicted maximum and minimum pressures in the product water delivery system with surge control installed are provided in Table B1 of Appendix B inside this report. The report also discusses necessary upgrades to the pipelines to make it hydraulically feasible to supply product water to the delivery system.

The product water delivery system includes several existing transmission mains: the OC-44 Transmission Main, East Orange County Feeder No. 2 (EOCF#2), the Aufdenkamp Transmission Main, the Joint (formerly Tri-Cities) Transmission Main, the Irvine Cross Feeder (ICF), Orange County Feeder Extension (OCF Ext.), the Coastal Supply Line, West Orange County Water Board Feeder No. 1 (WOCWBF#1) and West Orange County Water Board Feeder No. 2 (WOCWBF#2). The product water delivery system will also include a PRC proposed pipeline between the desalination plant and the existing OC-44 Transmission Main. The surge computer model was setup based on data gathered for the existing transmission mains from alignment and elevation drawings that were supplied by the Metropolitan Water District of Southern California, the City of Huntington Beach, and other agencies. The product water delivery system will also include three proposed booster pump stations: one planned for installation at the desalination plant (BPS#1), a second near the San Joaquin Reservoir (BPS#2) and a third at Coastal Junction (BPS#3). In addition, a new pump will be installed at an existing fourth booster pump station on WOCWBF#2 (BPS#4) to provide for product water delivery to agencies north of Huntington Beach.

The results of the pressure surge analysis of the product water delivery system show that the most significant hydraulic transient events will result from a loss of power to the booster pump stations. Power failures are typically unpredictable and will therefore occur at the booster pump stations at irregular intervals. Following a loss of power to the pumps, there will be a rapid drop in both the flow rate and discharge pressure combined with a rapid increase in the suction pressure at the booster pump stations. The results of the power failure simulations for the system show that traveling low-pressure (i.e., pressure drop) waves will be created on the discharge side of each of the booster pump stations by the drop in pressure. Simultaneously, a pressure upsurge wave is created on the suction side of each booster pump station following pump power failure. These high and low pressure waves will propagate out from the booster pump stations and into the suction and discharge pipelines, respectively, toward the demand locations and other booster pump stations.

The maximum hydraulic grade line (HGL) elevation that results from the upsurge created by a loss of power to BPS#2 is predicted to exceed the set point HGL of the pressure relief valve at STA 254+00 on the OC-44 Transmission Main. The opening of the pressure relief valve creates a pressure drop wave that, in combination with the pressure drop wave created by the loss of power to BPS#1, is predicted to drop the minimum HGL elevation sufficiently to create vapor pressure in both the proposed PRC Pipeline and OC-44 Transmission Main. Similarly, a pressure upsurge wave created by BPS#3 will propagate from EOCF#2 into the ICF and OCF Ext. and is predicted to exceed the maximum allowable HGL in the ICF as well as the set point HGL

elevation for the pressure relief valve at STA 1773+82 (Red Lion) on the OCF Ext. The opening of the OCF Ext. pressure relief valve also generates a significant pressure drop wave that is predicted to create vapor pressure in the pipeline. Vapor pressure conditions are also predicted in the ICF and Joint Transmission Mains following loss of power to the booster pump stations.

The duration of the low pressure will be long enough for vapor cavities to form in the pipelines. Upon re-pressurization of the pipelines by water hammer wave reflections, any vapor cavities that form will collapse and in the process produce very large magnitude positive pressures that could damage the pipelines and possibly create premature leaks. When subjected to negative pressures, a leak may become a source of pathogen intrusion. If the pipelines do not have sufficient strength, they may collapse under the large magnitude negative pressures associated with vapor pressure. In addition, the combination air and vacuum relief valves installed on the existing transmission mains are predicted to slam closed upon re-pressurization of the pipeline, which could damage the floats and create additional adverse pressures in the product water delivery system.

To eliminate the possibility of vapor cavity formation and collapse in the transmission mains and over-pressurization of the ICF, NHC recommends a surge control strategy that involves the installation of pressurized surge tanks at BPS#1 and BPS#2 in combination with the installation of vacuum relief valves with controlled venting features on the transmission mains. The properties of the recommended pressurized surge tanks are summarized in Table ES1.

Table ES1: Properties of recommended pressurized surge tanks

Properties	*BPS#1 (Discharge)*	*BPS#2 (Suction)*	*BPS#2 (Discharge)*
Tank Volume (ft^3)	2940	3393	1257
Tank Diameter (ft)	12	12	10
Tank Length (ft)	26	30	16
Orifice Diameter (in)	24	24	24
Inlet/Outlet losses (*k*)	3/3	3/3	3/3
Air Content (%)	30	45	30
Min. Pressure Rating (psi)	250	200	250

A 36-inch diameter bypass pipeline equipped with a check valve that permits flow from the suction to the discharge side of the pump station when the suction pressure exceeds the discharge pressure should be installed at BPS#2.

Although it is not necessary to install a pressurized surge tank on either the suction or discharge sides of BPS#3 and BPS#4 it will be necessary to install additional vacuum relief valves at several locations in the product delivery system. More specifically, it is recommended that vacuum relief valves with controlled venting features (e.g., APCO S-1500C, Valmatic VM-1800VB/38, or equivalent) be installed at the locations in the product water delivery system shown in Table 4 of this report, which also lists the recommended minimum diameter for the vacuum relief valves. Alternatively, slow closing air/vacuum valves (e.g., APCO Series 1700, or equivalent) or single-body vacuum relief valves (e.g., Vent-O-Mat RBXb) equipped with a bias mechanism could be installed. Note that the static pressure at each location should be carefully compared to the required minimum seating pressure before selecting single body vacuum relief valves. The vacuum relief valves should be duplicated to provide redundancy in case a valve fails to open, opens too slowly, or is removed for service. Regular maintenance should be performed on the vacuum relief valves to ensure that they are always in good working order.

Some of the locations listed in Table 4 may already be equipped with combination air and vacuum relief valves for filling and draining. If equivalent or larger diameter vacuum relief valves than those recommended in Table 4 are already installed, additional vacuum relief valves need not be installed at these locations.

It may be possible to slightly reduce the volume of the recommended pressurized surge tank on the suction side of BPS#2 by installing a surge relief valve equipped with an anticipatory feature on the suction side of the booster pump station. However, the surge relief valve would potentially discharge a significant quantity of treated water to waste that would have to be de-chlorinated prior to disposal. Additional pressure surge analyses would be required to size the surge relief valve and re-size the surge tank.

A booster pump station startup analysis presented in this report shows that switching the water delivery system from MWD water to desalination plant product water without interrupting the water supply to customers is hydraulically feasible. In order to switch the supply from MWD water to desalination plant product water it is recommended that the pumps at the booster pump stations be ramped up to full speed in 200 seconds or longer. The pumps at BPS#1, BPS#2, and BPS#3 should be started one at a time with at least a 500 second lag between each pump start. The pumps at BPS#4 should also be started one at a time, but only a 200 second lag between each pump start is required. The pumps at each booster pump station can be started in any order. Approximate opening and closing times for the pressure and flow control facilities in the product delivery system are described in Section 6 of this report.

Future Pressure Surge Analysis Required

This pressure surge analysis was performed at a preliminary planning stage of the Huntington Beach Seawater Desalination Plant Project. Therefore, it is important to note that both the results of the pressure surge analysis and the recommended surge control measures for the booster pump stations and product water delivery system that are presented in this report should be checked and, if necessary, updated as the designs for the booster pump stations are more fully developed. This is because the recommendations provided in this report are somewhat sensitive to the selected pumps and valves, which have yet to be finalized.

Necessary Upgrades to the Product Water Delivery System

The following hydraulic upgrades, which are unrelated to surge control, should be made to the transmission mains to facilitate delivery of the desalination plant product water.

1. A 42-inch diameter bypass equipped with a hydraulically operated isolation valve (e.g., ball, plug or cone valve) should be installed at the existing pressure control structure located at STA 254+00 on the OC-44 Transmission Main. The bypass will permit the pumping of product water around the pressure control structure, which will be closed at the time. The pressure control structure will be open and the isolation valve will be closed when, as is currently the case, MWD water is supplied to the OC-44 Transmission Main.

2. A pressure control valve should be installed near STA 1237+79 on EOCF#2, which is upstream of the connection to the ICF. The pressure control valve should be set to maintain a downstream hydraulic grade line elevation that is less than 478 ft, which will

prevent over-pressurization of the ICF and spillage of product water to the San Joaquin Reservoir when BPS#2 is operating.

3. The existing pressure relief valve at STA 1090+95 on EOCF#2, which is currently set to open at an HGL elevation of approximately 485 ft, should be locked out when BPS#2 is operating. This will prevent the pressure relief valve from opening, which is not required when product water is supplied to the delivery system.

Previous Pressure Surge Analysis Work

Note that a pressure surge analysis previously performed by Dr. Axworthy (who is also an author of this report) in 2005 did not include WOCWBF#1 and WOCWBF#2 in Huntington Beach or BPS#4. Furthermore, the PRC proposed total dynamic head (TDH) for BPS#2 has been significantly reduced since the 2005 surge analysis was performed. For these reasons, this report supersedes all the work presented in the 2005 surge analysis.

2.0 Introduction

Poseidon Resources Corporation (PRC) is planning a 50 million gallon per day (MGD) seawater desalination plant for the City of Huntington Beach, California and retained Northwest Hydraulic Consultants, Inc. (NHC) to perform a pressure surge analysis for the operation of the plant and the associated product water delivery system. This report presents findings from the pressure surge analysis, which includes the results of pump power failure and start up simulations and recommendations for surge control. Several operating scenarios were evaluated as part of the pressure surge analysis.

Currently, the Metropolitan Water District of Southern California's (MWD) Diemer Water Filtration Plant supplies water to the delivery system via Coastal Junction, the West Orange County Feeder, and the Orange County Feeder. Under the proposed operation, several booster pump stations and associated valves will be installed and product water from the desalination plant will supply the majority of water demand in the delivery system described below.

A booster pump station (BPS#1) is planned for installation at the seawater desalination plant and will deliver flow through a proposed 48-inch diameter pipeline that will be constructed between the desalination plant and the OC-44 transmission main. The alignment of this pipeline has yet to be finalized, but it is anticipated that PRC pipeline will in part follow the alignment of the OC-44 transmission main. More specifically, the PRC pipeline will replace the existing OC-44 transmission main from the intersection of Brookhurst Street and Adams Avenue to just east of the intersection of Del Mar Avenue and Newport Boulevard where it will connect to the existing 42-inch diameter OC-44 transmission main. At the intersection of Brookhurst Street and Adams Avenue the PRC pipeline will connect to the existing 30-inch diameter Huntington Beach OC-44 Transmission Main via a flow control valve and supply both West Orange County Water Board Feeder No. 1 (WOCWBF#1) and West Orange County Water Board Feeder No. 2 (WOCWBF#2).

A second booster pump station (BPS#2) is planned for installation near the San Joaquin Reservoir. BPS#2 will take suction from the OC-44 Transmission Main and deliver product water to Coastal Junction via East Orange County Feeder No. 2 (EOCF#2) and to the Irvine Cross Feeder (ICF). A pressure control valve will be installed on EOCF#2 upstream of STA 1237+79 between BPS#2 and the ICF to prevent over-pressurization of the ICF when BPS#2 is operating. Product water will be supplied to the Orange County Feeder Extension (OCF Ext.) and the Coastal Supply Line via the ICF.

A third booster pump station (BPS#3) is planned for installation near Coastal Junction, which will be closed to EOCF#2 when BPS#3 is operating. BPS#3 will take suction from EOCF#2 and will increase the pressure sufficiently to supply water, in addition to that supplied by the Diemer Water Filtration Plant, to both the Aufdenkamp and Joint (formerly Tri-Cities) Transmission Mains.

A fourth existing booster pump station (BPS#4) is located near the Huntington Beach metering structure, which is just south of the intersection of Springdale Street and Briarcliff Drive. A new pump will be installed at BPS#4 and will take suction from the Huntington Beach Distribution System and deliver up to 17 MGD of product water to several reaches of WOCWBF#2 north of Huntington Beach. The flow control structure at this location, which normally delivers MWD water from the West Orange County Feeder to Huntington Beach, will be closed if BPS#4 is operating and the flow in WOCWBF#2 is reversed.

The results of the pressure surge analysis of the delivery system that was performed by NHC are described in this report along with recommendations to protect the delivery system from adverse pressure surges caused by the operation of the proposed and existing booster pump stations. Both pump power failure and pump startup simulations were performed for the booster pump stations and the results of the simulations are included in the report. Also, movies of the most pertinent pressure surge analysis simulations are included on a CDROM in Appendix A and can be viewed with Microsoft Corporation's Windows Media Player© or other comparable software.

The report also includes a description of the pressure surge analysis modeling approach, which is the focus of the next section.

3.0 Unsteady Flow and Hydraulic Transient Analysis

Unsteady flow in pipelines can be represented by a set of one-dimensional hyperbolic partial differential equations. In their simplified hydraulic grade line form, the continuity and momentum equations are[1]

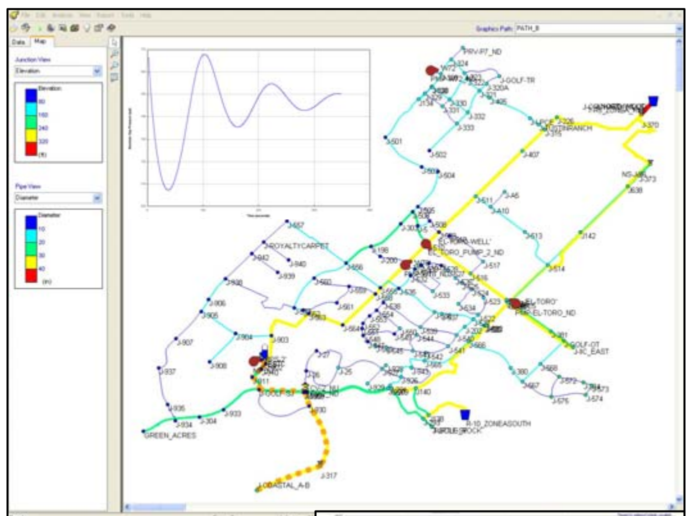
$$\frac{a^2}{g}\frac{\partial v}{\partial x}+\frac{\partial H}{\partial t}+v\frac{\partial H}{\partial x}=0 \qquad (1)$$

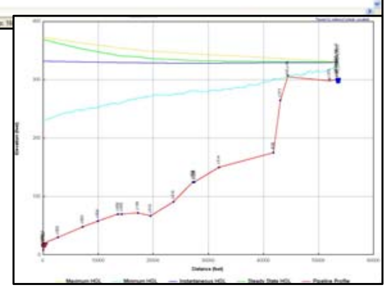
$$\frac{\partial v}{\partial t}+v\frac{\partial v}{\partial x}+g\frac{\partial H}{\partial x}+\frac{4}{\rho D}\tau=0 \qquad (2)$$

in which t = time; x = distance along the pipe centerline; H = piezometric head (i.e., elevation plus pressure head); a = acoustic wavespeed; v = average fluid velocity; g = acceleration due to gravity; D = inside diameter of the pipe; ρ = mass density of the fluid; and τ = shear stress at the pipe wall. Line pressure (lb/ft^2) can be calculated as the product of the specific gravity (1.0 for water) and specific weight of water (i.e., 62.4 lb/ft^3), and the pipeline pressure head (ft). The wall shear stress can be approximated as $\tau = \rho f |v| v/8$ where f = Darcy-Weisbach friction factor for steady pipe flow.

The Method of Characteristics (MOC) is considered the most numerically efficient solution of the above continuity and momentum equations when modeling transient pressures in pipe systems.[1,2] Solving these equations using the MOC yields a system of ordinary differential equations. Following integration, these equations may be written in their simplified form and solved for the head and flow at pipe junctions and boundary conditions using the approach of Karney and McInnis, 1992[2].

NHC constructed a hydraulic transient analysis model of the system and associated facilities using the TransAM hydraulic transient analysis software. This MOC based computer model has been used to perform both steady state and hydraulic transient analyses of pipelines with diameters as large as 22 ft and flow rates up to 1,485 cfs.





TransAM Transient Analysis Software

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[1] Wylie, E.B., and Streeter, V.L. (1993). *Fluid Transients in Systems.* Prentice-Hall, Englewood Cliffs, NJ.

[2] Karney, B.W., and McInnis, D. (1992). “Efficient calculation of transient flow in simple pipe networks.’’ *Journal of Hydraulic Engineering,* ASCE, 118(7), 1014-1030.

TransAM has been extensively verified by comparison of computed transient pressures and flows with those measured in the field (e.g., Axworthy and Chabot, 2004[3]) and laboratory (e.g., Axworthy, et al., 2000[4]), and predicted by codes developed by others.

The TransAM code, which was originally developed in 1984 and is co-authored by NHC's lead for pressure surge analysis, Dr. Axworthy, is compiled with the most recent version of Intel Visual Fortran so as to fully leverage the computing power of the Intel Core 2 Duo processor and is one of the first transient analysis programs to fully exploit the parallel processing capabilities of this multi-core processor. The resulting fast computer execution time makes the transient analysis software ideal for performing analyses of large and complex pipeline systems.

[3] Axworthy, D.H. and Chabot, N. (2004). "Pressure transients in a Canadian sewage force main." *Canadian Journal of Civil Engineering*, NRC, Canada, 31, 1039-1050.

[4] Axworthy, D.H., Ghidaoui, M.S., and McInnis, D.A. (2000). "Extended thermodynamics derivation of energy dissipation in unsteady pipe flow." *Journal of Hydraulic Engineering,* ASCE, 126(4), 276-287.

4.0 System Facilities and Characteristics

Figure 1 shows a schematic of the delivery system that will be supplied product water from the proposed Huntington Beach Desalination Plant. Nine pipeline graphic paths are shown in Figure 1 and will be referenced later in the report to illustrate the maximum and minimum pressure envelopes resulting from the pressure surge analysis.

A booster pump station (BPS#1) will be installed at the 50 MGD seawater desalination plant and will deliver product water through a proposed 48-inch diameter pipeline that will be constructed between the seawater desalination plant and the OC-44 Transmission Main. The alignment of this pipeline has yet to be finalized, but it is anticipated that PRC pipeline will in part follow the alignment of the OC-44 transmission main. More specifically, the PRC pipeline will replace the existing OC-44 transmission main from the intersection of Brookhurst Street and Adams Avenue to just east of the intersection of Del Mar Avenue and Newport Boulevard where it will connect to the existing 42-inch diameter OC-44 Transmission Main. At the intersection of Brookhurst Street and Adams Avenue the PRC pipeline will connect to an existing 30-inch Huntington Beach OC-44 Transmission Main via a flow control valve and supply both Huntington Beach and WOCWBF#2. Path A in Figure 1 shows the alignment of the PRC Pipeline and OC-44 Transmission Main.

Figure 1 shows that there is an existing in-line pressure control structure installed on the OC-44 Transmission Main at about STA 254+00. This pressure control station normally reduces the downstream pressure to less than 150 psi when MWD is supplying water to the OC-44 Transmission Main. However, when BPS#1 is operating this pressure control structure will be closed. To facilitate pumping around the pressure control structure a 42-inch diameter bypass equipped with a hydraulically operated isolation valve (e.g., ball, plug or cone valve) will be installed and opened prior to starting the pumps.

A 16-inch diameter pressure relief valve is currently installed on the west side of the STA 254+00 pressure control structure, which is the downstream or low pressure side of the pressure control structure when MWD is supplying water to the OC-44 Transmission Main. The pressure relief valve is set to open and discharge to waste when the pressure at that location exceeds 180 psi, which is equivalent to a HGL elevation of 438 ft.

Although there are numerous combination air and vacuum valves (CAV) installed on the OC-44 Transmission Main only the 3-inch diameter CAV currently installed at STA 453+08 has a role in the surge control strategy, which is discussed later in this report.

A second booster pump station (BPS#2) is proposed for installation at the junction of the OC-44 Transmission Main and East Orange County Feeder No. 2 (EOCF#2). BPS#2 will deliver product water to Coastal Junction via EOCF#2 and to the Irvine Cross Feeder (ICF), which is near the San Joaquin Reservoir.

A CAV of unspecified diameter is installed at STA 1194+94 on EOCF#2, which is a prominent highpoint on the pipeline between Coastal Junction and the San Joaquin Reservoir.

Figure 1 shows that there is a pressure relief valve installed at STA 1090+95 on EOCF#2. This pressure relief valve is normally (i.e., when MWD is supplying water to EOCF#2 via Coastal Junction) set to open and discharge to waste when the HGL elevation at this location exceeds 485 ft. However, when the booster pump stations are operating and delivering product water to

EOCF#2 this pressure relief valve will be locked out so that it does not open when the HGL in EOCF#2 exceeds 485 ft.

The Santiago Creek Pressure Control Structure (PCS) shown in Figure 1 between the Diemer Water Filtration Plant and Coastal Junction on EOCF#2 is set to reduce the downstream HGL elevation to 675 ft or lower.

Path B in Figure 1 shows the alignment of EOCF#2 between BPS#2 and the Diemer Water Filtration Plant via Coastal Junction.

A third booster pump station (BPS#3) is planned for installation near Coastal Junction, which will be closed to EOCF#2 when BPS#3 is operating. BPS#3 will take suction from EOCF#2 and will increase the pressure sufficiently to supply water, in addition to that supplied by the Diemer Water Filtration Plant, to both the Aufdenkamp and Joint (formerly Tri-Cities) Transmission Mains. Connections from BPS#3 to these transmission mains will be made downstream of the CM-10 and CM-12 pressure control valves. Paths C and D in Figure 1 show the alignment of the Aufdenkamp and Joint Transmission Mains, respectively.

As shown in Figure 1 there are two (2) pressure control valves installed on the Aufdenkamp Transmission Main. These valves are currently set to reduce the downstream HGL elevation to 480 ft and 440 ft or lower. This figure also shows that a 2-inch diameter CAV is installed at the highpoint on the Aufdenkamp Transmission Main.

The ICF supplies both the Orange County Feeder Extension (OCF Ext.) and the Coastal Supply Line. Path E in Figure 1 shows the alignment of the ICF. For this analysis, it was assumed that a pressure control valve with a downstream set point HGL elevation less than 478 ft will be installed on EOCF#2 between BPS#2 and the ICF to prevent over-pressurization of the ICF and to prevent spilling water into the San Joaquin Reservoir through the associated air gap (El. 478 ft) at that location when BPS#2 is in operation.

Figure 1 shows that a pressure control structure is installed at Willits Street on the OCF Ext. and is set to reduce the downstream HGL elevation to 475 ft or lower. Further downstream at about STA 1773+82 on the OCF Ext. the Red Lion pressure relief valve is set to open and discharge to waste when the HGL elevation at that location exceeds 490 ft. At the junction of the OCF Ext. and the ICF the Irvine Regulating Structure is set to reduce the downstream HGL elevation in the OCF Ext. to 310 ft or lower. There is a 4-inch diameter CAV installed at STA 2048+82 on the OCF Ext., which is a significant highpoint on the pipeline. A standpipe located at STA 2075+75 on the OCF Ext. will discharge to the Big Canyon Reservoir when the HGL elevation at that location exceeds 320 ft. Path F in Figure 1 shows the alignment of the OCF Ext.

There is a flow control valve (i.e., CM-01) installed at the junction of the OCF Ext. and the Coastal Supply Line. Path G in Figure 1 shows the alignment of the Coastal Supply Line.

A fourth existing booster pump station (BPS#4) is located near the Huntington Beach metering structure, which is just south of the intersection of Springdale Street and Briarcliff Drive. A new pump will be installed at BPS#4 and will take suction from the Huntington Beach Distribution System and deliver up to 17 MGD of product water to several reaches of WOCWBF#2 that are north of Huntington Beach. The existing pressure control valve at this location, which normally delivers MWD water from the West Orange County Feeder to Huntington Beach (HGL = 210 ft or lower), will be closed when BPS#4 is operating. The new pump at BPS#4 will be in parallel with the pressure control valve. Paths H and I in Figure 1 show the alignments of WOCWBF#2 and WOCWBF#1, respectively.

There is a pressure control valve on WOCWBF#1 that is located near the intersection of Newland Street and Edinger Avenue, which is set to reduce the downstream HGL elevation to about 220 ft or lower.

Pressure control valves on WOCWBF#1 and WOCWBF#2 that are installed near the Intersection of Katella Avenue and Dale Street are supplied MWD water from the West Orange County Feeder and reduce the downstream HGL elevation to about 360 ft or lower.

Four (4) 8-inch diameter pressure relief valves, each set to open and discharge to waste when the pressure exceeds 140 psi, are installed on the low pressure sides of the pressure control valves that are located on WOCWBF#1 and WOCWBF#2.

Lengths, diameters and elevations for the delivery system transmission mains and pipelines were obtained from engineering design drawings and water models supplied by PRC via their subconsultant, ID Modeling (IDM). IDM also provided system demands and pipe diameters and lengths for segments of WOCWBF#1 and WOCWBF#2 for which engineering design drawings were not available.

The maximum allowable pressure under surge conditions for the steel and concrete delivery system transmission mains and pipelines is equal to the working (in some cases static) pressure plus a 33 percent surge allowance (based on the working or static pressure of the piping).

In some cases, the allowable pressure for a pipeline was specified in terms of HGL elevation. For example, pipe strength calculations performed by MWD show that the maximum allowable working HGL elevation in EOCF#2 between Coastal Junction and the ICF is about 640 ft. For this surge analysis, a 33 percent surge allowance was employed for EOCF#2. In another case, MWD specified that the maximum allowable HGL elevation in the ICF is 485 ft.

Selection of formal performance curves for the pumps that will be installed at the proposed booster pump stations is beyond the scope of this analysis. However, in order to perform the pressure surge analysis NHC used performance curves and characteristics for the pumps at each booster pump station that were appropriate to meet the anticipated capacity and head requirements specified in the water models provided by IDM. The performance curves and characteristics utilized for this pressure surge analysis should be checked as the booster pump station design proceeds.

The pumps proposed for installation at the booster pump stations were modeled as vertical turbine pumps. Table 1 lists the assumed rated characteristics for the pumps at each booster pump station. The total polar moment of inertia (WR^2) of the rotating parts of each pump-motor unit was estimated from pump and motor manufacturers' catalog data. The pumps at each booster pump station were modeled as if they were equipped with 36-inch diameter swing check valves (C_v = 18,000 gpm/$\sqrt{\text{ft}}$). It was also assumed that the pumps at each booster pump station will be equipped with soft-start motors or variable frequency drives (VFD).

Table 1: Rated characteristics for the pumps at the booster pump stations

Characteristic	***BPS#1***	***BPS#2***	***BPS#3***	***BPS#4***
No. of Pumps	3	3	3	2
Rated Discharge/Pump (gpm)	11,574	10,370	6015	6059
Rated Discharge/Pump (MGD)	16.7	14.9	8.7	8.7
Rated Head (ft)	452	190	190	230
Rated Speed (rpm)	1780	1780	1780	1780
Rated Efficiency (%)	84	84	84	84
Motor Power (hp)	1750	700	400	450
Inertia, WR^2 ($lb\text{-}ft^2$)	753	257	106	148

For this analysis, we have relied on data (e.g., engineering drawings, pipe lengths and diameters, water levels, etc.) provided by the PRC via IDM. Should any component of this system be significantly modified relative to its current design as specified above, it may be necessary to check the results of the analysis and recommendations with the modified design.

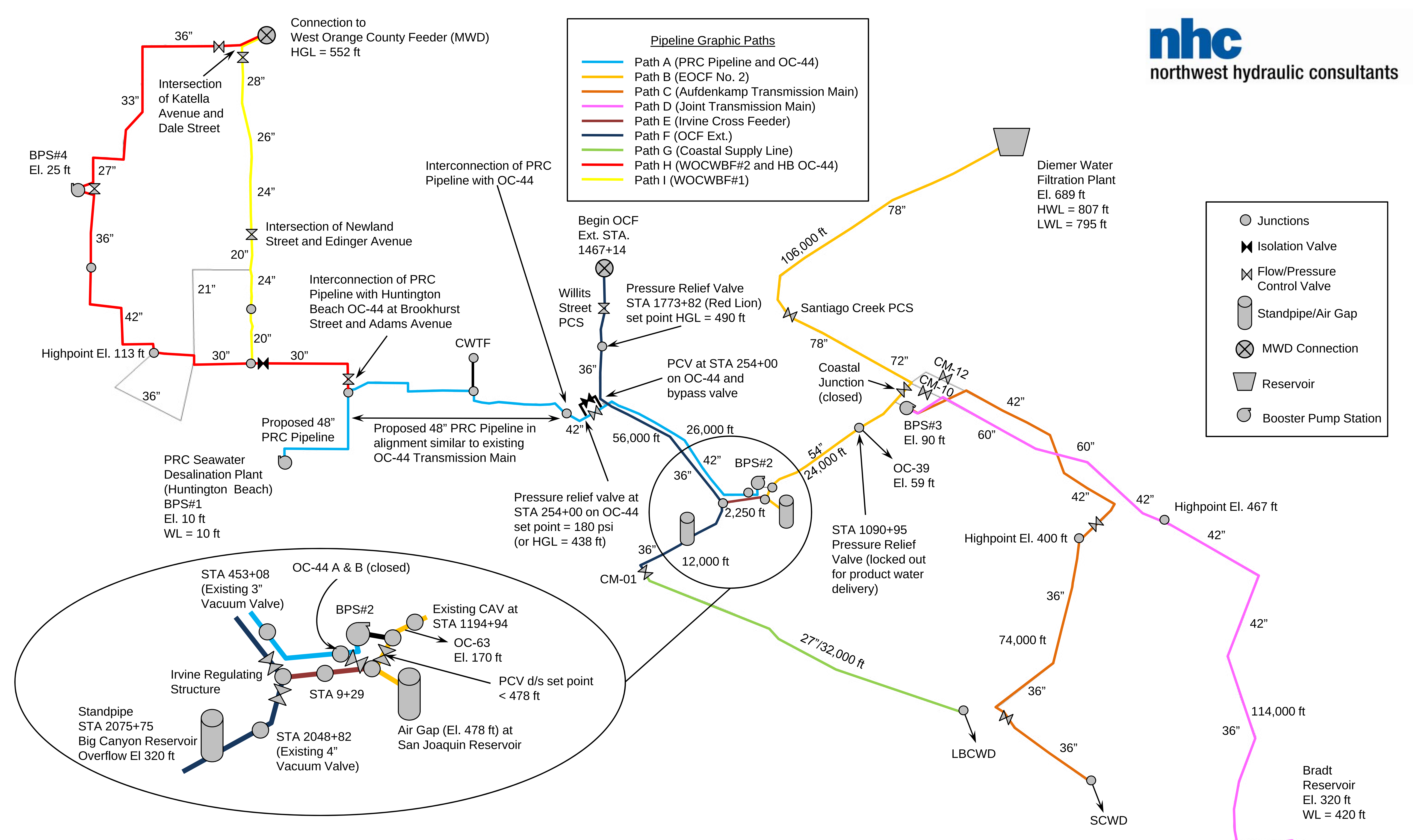

Figure 1: Schematic of Proposed PRC Huntington Beach Seawater Desalination Plant Product Water Delivery System

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5.0 Steady State Operating Scenarios

Three (3) possible steady state operating scenarios for the Huntington Beach Seawater Desalination Plant and product water delivery system were provided by PRC via IDM. These operating scenarios focus on different levels of product water supply to the City of Huntington Beach, in particular the product water supply to WOCWBF#1 and WOCWBF#2. The operating scenarios are described in more detail as follows:

1. Operation of the Huntington Beach Seawater Desalination Plant at 50 MGD with all of the product water being supplied to the OC-44 Transmission Main and zero product water being supplied to Huntington Beach and WOCWBF#1 and WOCWBF#2. Under this scenario BPS#1, BPS#2 and BPS#3 will operate and BPS#4 will be idle. Coastal Junction and both CM-10 and CM-12 will be closed so that only product water will be supplied to the Joint and Aufdenkamp Transmission Mains. The pressure control structure at STA 254+00 on the OC-44 Transmission Main will be closed and the proposed bypass at the same location will be open to permit pumping from BPS#1 to BPS#2. The flow control valve between the proposed PRC pipeline and the existing 30-inch diameter pipeline to Huntington Beach will provide up to 3.57 MGD of product water to supply a demand just upstream of the closed connection to WOCWBF#1 and WOCWBF#2. All the demands on WOCWBF#1 and WOCWBF#2 will be supplied MWD water from the West Orange County Feeder.

2. Operation of the Huntington Beach Seawater Desalination Plant at 50 MGD with 28 MGD of the product water being supplied to the OC-44 Transmission Main and 22 MGD of product water being supplied to Huntington Beach. Under this scenario BPS#1, BPS#2 and BPS#3 will operate and BPS#4 will be idle. Coastal Junction will be closed and both CM-10 and CM-12 will be open so that a mix of MWD and product water will be supplied to the Joint and Aufdenkamp Transmission Mains. The pressure control structure at STA 254+00 on the OC-44 Transmission Main will be closed and the proposed bypass at the same location will be open to permit pumping from BPS#1 to BPS#2. The WOCWBF#2 pressure control valve at BPS#4 will be closed and the pressure control valve on WOCWBF#1 at the intersection of Newland Street and Edinger Avenue (see Figure 1) will be open. All the demands on the WOCWBF#2 north of BPS#4 and on the WOCWBF#1 north of the pressure control valve at the intersection of Newland Street and Edinger Avenue will be supplied MWD water from the West Orange County Feeder.

3. Operation of the Huntington Beach Seawater Desalination Plant at 50 MGD with 28 MGD of the product water being supplied to the OC-44 Transmission Main, 5 MGD of product water being supplied to Huntington Beach, and 17 MGD being supplied to WOCWBF#2 north of Huntington Beach (i.e., north of BPS#4). Under this scenario all the booster pump stations, including BPS#4, will operate. Coastal Junction will be closed and both CM-10 and CM-12 will be open so that a mix of MWD and product water will be supplied to the Joint and Aufdenkamp Transmission Mains. The pressure control structure at STA 254+00 on the OC-44 Transmission Main will be closed and the proposed bypass at the same location will be open to permit pumping from BPS#1 to BPS#2. The WOCWBF#2 pressure control valve at BPS#4 will be closed and the pressure control valve on WOCWBF#1 at the intersection of Newland Street and Edinger Avenue (see Figure 1) will be open. All the demands north of the WOCWBF#1 pressure control valve at the intersection of Newland Street and Edinger Avenue will be supplied MWD water from the West Orange County Feeder.

For the above operating scenarios, the predicted steady state flow rate and TDH at each booster pump station are summarized in Table 2. These steady state operating conditions were used as a basis for the pressure surge analysis discussed in the next section.

Table 2: Predicted steady state booster pump station capacities

Operating Scenario	*BPS#1*		*BPS#2*		*BPS#3*		*BPS#4*	
	Flow (MGD)	*TDH (ft)*	*Flow (MGD)*	*TDH (ft)*	*Flow (MGD)*	*TDH (ft)*	*Flow (MGD)*	*TDH (ft)*
1	50	453	44.8	190	26	191	N/A	N/A
2	50	427	26	142	7.3	180	N/A	N/A
3	50	427	26	142	7.3	180	17	230

6.0 Pressure Surge Analysis

Pump power failure and startup simulations for the booster pump stations are presented in this section. In addition, surge control measures are recommended to protect the product water delivery system from adverse pressure surges created by a loss of power to the booster pump stations.

6.1 Pump Power Failure

Power failures are typically unpredictable and will therefore occur at the booster pump stations at irregular intervals. Following a loss of power to the pumps, there will be a rapid drop in both the flow rate and discharge pressure combined with a rapid increase in the suction pressure at the booster pump stations. The results of the power failure simulations for the system show that traveling low-pressure (i.e., pressure drop) waves will be created on the discharge side of each of the booster pump stations by the drop in pressure. Simultaneously, a pressure upsurge wave is created on the suction side of each of BPS#2, BPS#3 and BPS#4 following pump power failure. These high and low pressure waves will propagate out from the booster pump stations and into the suction and discharge pipelines, respectively, toward the demand locations and other booster pump stations.

Operating Scenario No. 1

The results of a pump power failure analysis for the first operating scenario defined in Section 5 are presented and represent the worst case surge conditions for the delivery system. Figure 2 depicts the maximum/minimum HGL envelope predicted by the transient simulation, the initial steady state HGL elevation, the pipeline elevation profile, the rated HGL (based on the available pressure class), and the maximum allowable HGL for the proposed PRC Pipeline and the OC-44 Transmission Main (i.e., Path A in Figure 1) following booster pump station power failure. As this figure shows, the maximum HGL elevation that results from the upsurge created by a loss of power to BPS#2 is predicted to exceed the set point HGL of the pressure relief valve at STA 254+00 on the OC-44 Transmission Main. The opening of the pressure relief valve creates a pressure drop wave that, in combination with the pressure drop wave created by the loss of power to BPS#1, is predicted to drop the minimum HGL elevation sufficiently to create vapor pressure in both the PRC Pipeline and OC-44 Transmission Main. The duration of the low pressure will be long enough for vapor cavities to form in the PRC Pipeline and OC-44 Transmission Main. Upon re-pressurization of the pipelines by water hammer wave reflections, any vapor cavities that form will collapse and in the process produce very large magnitude positive pressures that could damage the pipelines. When subjected to negative pressures, Any resulting leaks may become a source of pathogen intrusion. In addition, the existing CAVs installed on the OC-44 Transmission Main are predicted to slam closed upon re-pressurization of the pipeline, which could damage the floats and create additional adverse pressures.

As noted in Figure 2, the results presented in this figure do not reflect the large magnitude positive pressures that are created by vapor cavity collapse because it is impossible to predict with any certainty the magnitude and location of positive pressures associated with the collapse of a vapor cavity. However, it is known that the magnitude of these positive pressures may be in excess of 300 psi (Bergant and Simpson, 1999)[5], which when added to the steady state pressure in the pipelines greatly exceeds the maximum allowable pressure for the OC-44 Transmission Main. For this reason, NHC recommends the complete elimination of the possible formation and collapse of vapor cavities in the pipelines to ensure safe operation of the system.

Figure 2 shows that near the OC-44 Transmission Main pressure relief valve the steady state HGL elevation is predicted to slightly exceed the rated HGL elevation of the OC-44 Transmission Main.

A movie of the simulation summarized in Figure 2 is provided on the CDROM enclosed as Appendix A. The movie, called `PathA-power-failure.avi` shows the animation of the HGL in the PRC Pipeline and OC-44 Transmission Main prior to and after loss of power to the booster pump stations. The movie file can be viewed with Microsoft Corporation's Windows Media Player© or other comparable software.

Figure 3 depicts the predicted pressure head histories at BPS#1, the interconnection of the PRC Pipeline to Huntington Beach (see Figure 1), the pressure relief valve at STA 254+00 on the OC-44 Transmission Main, and the CAV at STA 453+08 on the OC-44 Transmission Main following a loss of power to the booster pump stations. This figure shows that the pressure is predicted to drop to vapor pressure at BPS#1 and in the PRC Pipeline following booster pump station power failure and the subsequent opening of the pressure relief valve and discharge of fluid from the OC-44 Transmission Main. It also shows that the CAV at STA 254+00 is predicted to open, but does not have sufficient capacity to adequately protect the OC-44 Transmission Main at this location.

Figure 4 illustrates the results of the analysis for EOCF#2 (i.e., Path B in Figure 1) between the air gap at the San Joaquin Reservoir and Diemer WFP. This figure depicts the predicted steady state, maximum and minimum HGL elevations in EOCF#2 following a loss of power to BPS#2 and BPS#3. These results show that BPS#2 and BPS#3 will not over-pressurize EOCF#2 under steady state operation. It also shows that the maximum HGL is predicted to not exceed the rated HGL (based on the maximum working pressure) of EOCF#2 except between the proposed pressure control structure and the San Joaquin air gap, but not by more than 33 percent of the working pressure. The minimum HGL elevation is predicted to remain above the crown elevation of EOCF#2 except near BPS#2 and near STA 1194+94 where the pressure is predicted to drop to vapor pressure.

A movie of the simulation summarized in Figure 4 is provided on the CDROM enclosed as Appendix A. The movie, called `PathB-power-failure.avi` shows the animation of the HGL in EOCF#2 prior to and after loss of power to the booster pump stations.

Figure 5 depicts the predicted pressure head histories on the suction and discharge sides of BPS#2 and at STA 1194+94 and STA 1090+95 (OC-39) on EOCF#2 following pump power failure at the booster pump stations. This figure shows that the existing CAV at STA 1194+94 is predicted to open approximately 38 seconds after pump power failure. Note that if Coastal Junction is not opened following loss of power to the booster pump stations, the system demands, such as at OC-39, will gradually drain significant portions of the EOCF#2 between STA 1194+94 and Coastal Junction.

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[5] Bergant, A. and Simpson, A.R. (1999). "Pipeline column separation flow regimes.'' *Journal of Hydraulic Engineering,* ASCE, 125(8), 835-848.

The predicted maximum and minimum HGL elevations in the Aufdenkamp (Path C) and Joint (Path D) Transmission Mains are depicted in Figures 6 and 7, respectively. As these figures show, the maximum HGL elevation is predicted to not exceed the steady state HGL elevation following a loss of power to the booster pump stations. The minimum HGL elevation is predicted to remain above the crown elevation of the transmission mains except at the high points where, in the case of the Joint Transmission Main, the pressure is predicted to drop to vapor pressure if a CAV is not installed at that location.

A movie of the simulation summarized in Figure 6 is provided on the CDROM enclosed as Appendix A. The movie, called `PathC-power-failure.avi` shows the animation of the HGL in the Aufdenkamp Transmission Main prior to and after loss of power to the booster pump stations.

Figure 8 illustrates the predicted pressure head histories on the suction and discharge sides of BPS#3 and at the highpoints on the Aufdenkamp and Joint Transmission Mains. This figure shows that the existing CAV at the Aufdenkamp highpoint is predicted to open approximately 30 seconds after a loss of power to the booster pump stations.

Figures 9, 10 and 11 show the predicted maximum and minimum HGL elevations in the ICF (Path E) , OCF Ext. (Path F) and Coastal Supply Line (Path G) following booster pump station power failure. As Figure 9 illustrates, the maximum HGL elevation in the ICF is predicted to exceed the maximum allowable HGL elevation (485 ft). In addition, the minimum HGL elevation is predicted to drop sufficiently below the crown of the pipeline to create vapor pressure. Figure 10 shows that the maximum HGL is predicted to exceed the set point HGL elevation (490 ft) for the pressure relief valve at STA 1773+82 (Red Lion) on the OCF Ext., which causes the valve to open and discharge fluid to waste. The opening of the pressure relief valve creates a pressure drop wave that is predicted to drop the minimum HGL elevation sufficiently to create vapor pressure in significant portions of the OCF Ext. Figure 11 shows that the maximum HGL elevation is predicted to not exceed the steady state HGL elevation and the minimum HGL elevation is predicted to remain above the crown elevation of the Coastal Supply Line following a loss of power to the booster pump stations.

A movie of the simulation summarized in Figure 9 is provided on the CDROM enclosed as Appendix A. The movie, called `PathE-power-failure.avi` shows the animation of the HGL in the ICF prior to and after loss of power to the booster pump stations.

The results of the analysis presented in Figures 9 and 10 differ from those results presented in the 2005 pressure surge analysis performed by Dr. Axworthy because in this analysis the TDHs for the pumps assumed for installation at BPS#2 and BPS#3 are different and, in the case of BPS#3 at least, create a larger magnitude pressure surge following loss of power than the pumps assumed for BPS#3 in the 2005 pressure surge analysis. More specifically, pumps with a rated head of 190 ft (in place of the 50 ft head pumps assumed for BPS#3 in the 2005 pressure surge analysis) are required for the current concept level design of the booster pump stations because the intended discharge HGL at BPS#2 and suction HGL at BPS#3 has been reduced by about 150 ft. Upon pump power failure a larger magnitude pressure upsurge is created on the suction side of BPS#3 by the higher head pumps. This upsurge wave propagates out from the suction side of BPS#3 and into EOCF#2 toward the San Joaquin Reservoir. It is also important to note that pumps and motors at BPS#2 will have a smaller magnitude polar moment of inertia than those assumed for the 2005 pressure surge analysis because the pumping head is significantly decreased at BPS#2 for this analysis. This means that the pressure drop wave created by these pumps following power failure will be less attenuated than it would be in the 2005 pressure surge analysis. Although the air gap at the San Joaquin Reservoir does, in part, attenuate the rapidly moving pressure surge waves created by BPS#2 and BPS#3 it is located too far from the junction of the ICF and EOCF#2 to prevent the HGL from exceeding the maximum allowable HGL (485 ft) for the ICF and subsequently opening the pressure relief valve on the OCF Ext. This means that, in the absence of additional surge control, the ICF could be over-pressurized and the OCF Ext. damaged by a loss of power to the booster pump stations.

The predicted pressure head histories at STA 9+29 on the ICF, at the OCF Ext. pressure relief valve and at STA 2048+82 on the OCF Ext. are depicted in Figure 12. This figure shows that the existing CAV at the STA 2048+82 on the OCF Ext. is predicted to open approximately 140 seconds after a loss of power to the booster pump stations. It also shows that the pressure relief valve on the same pipeline will open soon after pump power failure and that the pressure in the ICF is predicted to drop to vapor pressure.

Surge Control

Several surge control measures were considered for this system. Surge anticipating valves and surge relief valves were considered, but are not recommended for the discharge side of the booster pump stations because they will not prevent vapor cavity formation and collapse in the pipelines following pump power failure. A surge relief valve with an anticipator feature could be an effective means of controlling the upsurge on the suction sides of BPS#2 and BPS#3, but unfortunately there will not be provision at the booster pump stations to discharge large quantities of treated water to waste, which is typically necessary for this type of surge protection device. Variable frequency drives and soft stop motors will not function following a power outage at the booster pump stations and therefore will not prevent vapor cavity formation and collapse or over-pressurization of the pipelines following pump power failure. Flywheels are attractive due to zero maintenance requirements, but would be difficult to install on vertical turbine pumps, which are planned for the booster pump stations. For these reasons, NHC recommends a surge protection strategy that involves the installation of pressurized surge tanks in combination with vacuum relief valves.

To eliminate the possibility of vapor cavity formation and collapse, and over-pressurization in the product water delivery system following booster pump station power failure it is recommended that pressurized surge tanks be installed on the discharge side of BPS#1 and on both the suction and discharge sides of BPS#2. The lower portion of each pressurized surge tank would be filled with water and the upper portion would contain compressed air. Although it is not necessary to install a pressurized surge tank on either the suction or discharge sides of BPS#3 and BPS#4 it will, as discussed below, be necessary to also install additional vacuum relief valves at several locations in the product water delivery system and a bypass with check valve at BPS#2.

When a power failure occurs at a pump station fluid will begin flowing from the discharge side pressurized surge tank into the discharge pipeline to make up for the drop in flow at the pump station. The compressed air in the surge tank will expand as the water level in the tank drops. Since air is much more compressible than water the corresponding drop in pressure in the surge tank will not be as large as at the pump station. This means that the magnitude of the downsurge that propagates from the pump station into the pipeline will be significantly attenuated by the surge tank. Water will be delivered from the surge tank into the pipeline until the column of water comes to rest. The flow of water then reverses and flows back into the surge tank compressing the air and raising the pressure. The air is compressed until the reverse flow is halted. The air then expands as water is delivered back into the pipeline. The pressure and flow continue to cycle in this manner until the oscillations are damped by pipe friction and the system comes to rest at the static condition.

A similar, but opposite sequence of events takes place at the suction side pressurized surge tank. More specifically, when a power failure occurs at the pump station the compressed air in the suction surge tank will be compressed as water is forced into the tank from the suction pipeline limiting the upsurge. The surge tank will fill with water until the column of water in the suction pipeline comes to rest. The flow of water then reverses and flows back out of the suction pressurized surge tank, expands the air in the surge tank and lowers the pressure. The air will expand in the tank until the reverse flow is halted. The air will be compressed once again as water begins to flow back into the pressurized surge tank from the suction pipeline. The pressure and flow continue to cycle in this manner until, like on the discharge side of the pump station, the oscillations are damped by pipe friction and the system comes to rest at the static condition.

The recommended pressurized surge tank volumes are as follows:

- Install a minimum 2940 ft^3 (e.g., Diameter = 12 ft and Length = 26 ft, or an equivalent volume of 22,000 gallons) pressurized surge tank as close as possible to the discharge header at BPS#1.

- Install a minimum 3393 ft^3 (e.g., Diameter = 12 ft and Length = 30 ft, or an equivalent volume of 25,380 gallons) pressurized surge tank as close as possible to the suction header at BPS#2.

- Install a minimum 1257 ft^3 (e.g., Diameter = 10 ft and Length = 16 ft, or an equivalent volume of 9400 gallons) pressurized surge tank as close as possible to the discharge header at BPS#2.

For this analysis, it was assumed that the bottom elevation of the surge tanks would be a couple of feet above the elevation of the pump stations. The closer the pressurized surge tanks are located to the pump station headers, the more effective they will be at attenuating the magnitude of the pressure transients created by the loss of power to the pumps. Each surge tank should be connected to the respective header with a 24-inch diameter pipe. In each case, the connecting pipe should produce a head loss of approximately three (3) velocity heads for flow both into and out of the tank. In symbols, the head loss (h) is calculated as follows:

$$h = k\frac{v^2}{2g}$$

where k is the number of velocity heads (in this case 3), v is the maximum velocity in the connecting pipe between the surge tank and the header, and g is the acceleration due to gravity. During steady state operating conditions the suction surge tank at BPS#2 should contain an air volume equivalent to 45 percent of the total tank volume and the discharge surge tanks at BPS#1 and BPS#2 should each contain an air volume equivalent to 30 percent of the total tank volume. Horizontal or spherical surge tanks equipped with a compressor for level control would be suitable for installation at each location. The above surge tank recommendations are summarized in Table 3.

Table 3: Properties of recommended pressurized surge tanks

Properties	*BPS#1 (Discharge)*	*BPS#2 (Suction)*	*BPS#2 (Discharge)*
Tank Volume (ft^3)	2940	3393	1257
Tank Diameter (ft)	12	12	10
Tank Length (ft)	26	30	16
Orifice Diameter (in)	24	24	24
Inlet/Outlet losses (*k*)	3/3	3/3	3/3
Air Content (%)	30	45	30
Min. Pressure Rating (psi)	250	200	250

It is also recommended that a 36-inch diameter bypass pipeline equipped with a check valve that permits flow from the suction to the discharge side of the pump station when the suction pressure exceeds the discharge pressure be installed at BPS#2.

In addition to the surge tank protection, it is also recommended that vacuum relief valves with controlled venting features (e.g., APCO S-1500C, Valmatic VM-1800VB/38, or equivalent) be installed at the locations in the system shown in Table 4, which also lists the recommended minimum diameter for the vacuum relief valves.

Table 4: Recommended vacuum relief valves with controlled venting features

Transmission Main	*Location*	*Diameter (in)*
OC-44	STA 453+08	6
EOCF#2	STA 1194+94	4
Irvine Cross Feeder	STA 9+29 (highpoint)	4
Aufdenkamp	Highpoint*	3
Joint	Highpoint*	6
WOCWBF#2	Highpoint†	4

* See Figure 1
† Shown later in this report to be required for Operating Scenario No. 3 surge control (See Figure 1)

Alternatively, slow closing air/vacuum valves (e.g., APCO Series 1700, or equivalent) or single-body vacuum relief valves (e.g., Vent-O-Mat RBXb) equipped with a bias mechanism could be installed. Note that the static pressure at each location should be carefully compared to the required minimum seating pressure before selecting single body vacuum relief valves. The vacuum relief valves should be duplicated to provide redundancy in case a valve fails to open, opens too slowly, or is removed for service. Regular maintenance should be performed on the vacuum relief valves to ensure that they are always in good working order.

Some of the locations listed in Table 4 may already be equipped with combination air and vacuum relief valves for filling and draining. If equivalent or larger diameter vacuum relief valves than those recommended in Table 4 are already installed, additional vacuum relief valves need not be installed at these locations.

It may be possible to slightly reduce the volume of the recommended pressurized surge tank on the suction side of BPS#2 by installing a surge relief valve equipped with an anticipatory feature on the suction side of the booster pump station. However, the surge relief valve would potentially discharge a significant quantity of treated water to waste that would have to be de-chlorinated prior to disposal. Additional pressure surge analyses would be required to size the surge relief valve and re-size the surge tank.

Figures 13, 15, 17, 18, 20, 21 and 22 illustrate the results (i.e., predicted maximum and minimum HGL elevations) of the booster pump station power failure analysis with surge control installed for the proposed PRC Pipeline, OC-44 Transmission Main, EOCF#2, Aufdenkamp Transmission Main, Joint Transmission Main, ICF, OCF Ext., and Coastal Supply Line.

For all of the pipelines and transmission mains, the maximum pressures are predicted to not exceed the maximum allowable pressures. Most importantly, the maximum HGL elevations are predicted to not exceed the maximum allowable HGL elevation (485 ft) in the Irvine Cross Feeder and EOCF#2. Also, the maximum HGL elevations are shown to not exceed the set point HGL elevations for the pressure relief valves at STA 254+00 on the OC-44 Transmission Main and STA 1773+82 (Red Lion) on the OCF Ext, which means that these valves will remain closed. The minimum HGL elevations are shown to remain above the crown elevation of all of the pipelines and transmission mains except at the locations where vacuum relief valves are recommended for installation or are already installed.

Movies of the simulations summarized in Figures 13, 15, 17 and 20 are provided on the CDROM enclosed as Appendix A.

As shown in Figure 13, installation of surge control will not prevent the steady state HGL elevation from exceeding the rated HGL elevation near the OC-44 Transmission Main pressure relief valve. However, PRC and IDM can easily address this issue by slightly reducing the pumping head at BPS#1 and slightly increasing the pumping head at BPS#2.

Figures 14, 16, 19 and 23 depict the predicted pressure head histories at BPS#1, the PRC Pipeline Interconnection to Huntington Beach, the OC-44 pressure relief valve, the vacuum relief valve at STA 453+08 on the OC-44 Transmission Main, the suction and discharge sides of BPS#2, the vacuum relief valve at STA 1194+94 on EOCF#2, the OC-39 turn out from EOCF#2, the suction and discharge sides of BPS#3, the vacuum relief valves at the high points on the ICF, Aufdenkamp and Joint Transmission Mains, the pressure relief valve on the OCF Ext. (Red Lion), and the vacuum relief valve at STA 2048+82 on the OCF Ext. after a loss of power to the booster pump stations with surge control installed.

These figures show that the vacuum relief valves recommended in Table 4 are predicted to open following booster pump station power failure and that the proposed bypass valve at BPS#2 is predicted to open and close several times. Although not illustrated in these figures, the results of the analysis also show that water seals, equivalent to at least 16 percent of the total surge tank volume, are predicted to be maintained in each pressurized surge tank following booster pump station power failure.

Operating Scenario No. 2

A booster pump station power failure analysis was also performed for the second operating scenario defined in Section 5 assuming that the surge control recommended above is installed. In this case, 22 MGD of product water is supplied to Huntington Beach, and the remaining 28 MGD (in place of the 50 MGD analyzed in Operating Scenario No. 1) is supplied to the OC-44 Transmission Main and other pipelines.

Figures 24, 26, 28, 29, 31, 32 and 33 illustrate the results (i.e., predicted maximum and minimum HGL elevations) of the booster pump station power failure analysis with surge control installed for the proposed PRC Pipeline, OC-44 Transmission Main, EOCF#2, Aufdenkamp Transmission Main, Joint Transmission Main, ICF, OCF Ext. and Coastal Supply Line. Of particular interest in Operating Scenario No. 2 are the results of the analysis for WOCWBF#2 and WOCWBF#1, which are presented in Figures 35 and 36, respectively.

The maximum pressures are predicted to not exceed the maximum allowable pressures for all of the pipelines and transmission mains, including the Irvine Cross Feeder and EOCF#2. The pressure relief valves at STA 254+00 on the OC-44 Transmission Main and STA 1773+82 (Red Lion) on the OCF Ext are predicted to remain closed. The maximum HGL elevations are predicted to not exceed the steady state HGL elevations in WOCWBF#1 and WOCWBF#2 and the existing pressure relief valves on both transmission mains are predicted to remain closed. With the exception of the locations where vacuum relief valves are recommended for installation, or are already installed, the minimum HGL elevations are shown to remain above the crown elevation of all of the pipelines and transmission mains following loss of power to the booster pump stations. Figure 35 shows that the vacuum relief valve recommended for installation at the WOCWBF#2 highpoint is predicted to open after a loss of power to the booster pump stations.

Movies of the simulations summarized in Figures 35 and 36 are provided on the CDROM enclosed as Appendix A.

For the above booster pump station power failure analysis, Figures 25, 27, 30, 34 and 37depict the predicted pressure head histories at BPS#1, the PRC Pipeline Interconnection to Huntington Beach, the OC-44 pressure relief valve, the vacuum relief valve at STA 453+08 on the OC-44 Transmission Main, the suction and discharge sides of BPS#2, the vacuum relief valve at STA 1194+94 on EOCF#2, the OC-39 turn out from EOCF#2, the suction and discharge sides of BPS#3, the vacuum relief valves at the high points on the ICF, Aufdenkamp and Joint Transmission Mains and WOCWBF#2, the pressure relief valve on the OCF Ext. (Red Lion), and the vacuum relief valve at STA 2048+82 on the OCF Ext.

These figures show that most of the vacuum relief valves recommended in Table 4, which includes the vacuum relief valve at the highpoint of WOCWBF#2, are predicted to open following booster pump station power failure and that the proposed bypass valve at BPS#2 is predicted to open and close several times. Under this operating scenario the vacuum relief valves at the highpoints of the Aufdenkamp and Joint Transmission Mains are predicted to not open because the CM-10 and CM-12 pressure control structures provide sufficient flow to both transmission mains following booster pump station power failure to prevent the minimum HGL elevation from dropping below the crown elevation of the pipelines. Although not illustrated in these figures, the results of the analysis also show that water seals, equivalent to at least 11 percent of the total surge tank volume, are predicted to be maintained in each pressurized surge tank following booster pump station power failure.

Operating Scenario No. 3

In Operating Scenario No. 3 BPS#4, which is proposed for installation on WOCWBF#2 in Huntington Beach, is assumed to be initially operating along with BPS#1, BPS#2 and BPS#3. In this case, 5 MGD of product water is supplied to Huntington Beach and 17 MGD is supplied to WOCWBF#2 north of Huntington Beach via BPS#4. The remaining 28 MGD (in place of the 50 MGD analyzed in Operating Scenario No. 1) is supplied to the OC-44 Transmission Main and other pipelines.

The results (i.e., predicted maximum and minimum HGL elevations) of the booster pump station power failure analysis with surge control installed are presented in Figures 38, 40, 42, 43, 45, 46, 47, 49 and 50. The maximum pressures are predicted to not exceed the maximum allowable pressures for all of the analyzed pipelines and transmission mains, including WOCWBF#2 and WOCWBF#1. Although Figures 49 and 50 show that the maximum HGL elevations are predicted to exceed the steady state HGL elevations in WOCWBF#2 and WOCWBF#1 following a loss of power to BPS#4, the pressure relief valves installed on these pipelines are predicted to remain closed. Similarly, the pressure relief valves at STA 254+00 on the OC-44 Transmission Main and STA 1773+82 (Red Lion) on the OCF Ext are also predicted to remain closed following booster pump station power failure. These figures also show that the minimum HGL elevation is predicted to remain above the crown elevation of the pipelines except at the location of the vacuum relief valves.

Movies of the simulations summarized in Figures 49 and 50 are provided on the CDROM enclosed as Appendix A.

For the above booster pump station power failure analysis, Figures 39, 41, 44, 48 and 51 depict the predicted pressure head histories at BPS#1, the PRC Pipeline Interconnection to Huntington Beach, the OC-44 pressure relief valve, the vacuum relief valve at STA 453+08 on the OC-44 Transmission Main, the suction and discharge sides of BPS#2, the vacuum relief valve at STA 1194+94 on EOCF#2, the OC-39 turn out from EOCF#2, the suction and discharge sides of BPS#3, the vacuum relief valves at the high points on the ICF, Aufdenkamp and Joint Transmission Mains and WOCWBF#2, the pressure relief valve on the OCF Ext. (Red Lion), the vacuum relief valve at STA 2048+82 on the OCF Ext., and the suction and discharge sides of BPS#4.

As in Operating Scenario No. 2 above, these figures show that the vacuum relief valves at the highpoints of the Aufdenkamp and Joint Transmission Mains are predicted to not open because the CM-10 and CM-12 pressure control structures provide sufficient flow to both transmission mains following booster pump station power failure to prevent the minimum HGL elevation from dropping below the crown elevation of the pipelines. In addition, they show that the bypass valve proposed for installation at BPS#2 will be active and that most of the vacuum relief valves recommended in Table 4 are predicted to open following booster pump station power failure. In Figure 51, the suction pressure head is predicted to exceed the discharge pressure head, which means the check valves at the booster pump station will remain open until the PCV on WOCWBF#2 near the connection to the West Orange County Feeder is re-opened to raise the pressure in the pipeline. Here too water seals, equivalent to at least 11 percent of the total surge tank volume, are predicted to be maintained in each pressurized surge tank following a loss of power to the booster pump stations.

6.2 Pump Startup

Currently MWD water is supplied from the Diemer Filtration Plant via both EOCF#2 and the West Orange County Feeder to the transmission mains and pipelines shown in Figure 1. When the Huntington Beach Seawater Desalination Plant is brought on-line and the booster pump stations are started to supply up to 50 MGD of product water to the analyzed transmission mains and pipelines the MWD water supply will be reduced or, in some cases (e.g., PRC Pipeline, OC-44 Transmission Main, EOCF#2), stopped altogether. This will involve reversing the direction of flow in the PRC Pipeline, OC-44 Transmission Main and EOCF#2 and modulating some of the existing pressure control structures. The primary purpose of the startup analysis presented herein is to demonstrate that switching the water delivery system from MWD water to desalination plant product water without interrupting the water supply to customers is hydraulically feasible. In this section, the results of a concept-level booster pump station startup analysis are presented for the initial operating condition that all system demands are supplied MWD water.

For this analysis, the worst case condition involves startup of BPS#1, BPS#2 and BPS#3 and supply of all 50 MGD of product water to the OC-44 Transmission Main. MWD water will supply Huntington Beach and WOCWBF#1 and WOCWBF#2 before and after booster pump station startup. The results of a subsequent analysis presented below will consider BPS#4 startup separately.

When a pump at a booster pump station is started the pressure will increase rapidly and eventually exceed the pressure in the discharge pipeline. The check valve will open and the pump will deliver water into the discharge pipeline, which for the PRC pipeline between the desalination plant and the Huntington Beach connection will be initially filled with fluid at rest. The opening of the check valve will create a traveling pressure upsurge wave on the discharge side of a booster pump station and a traveling pressure downsurge wave on the suction side of a booster pump station that in each case will propagate into the associated transmission mains. Control of pressure surges that are created upon pump startup is simply a matter of controlling the rate of fluid acceleration at the pumps. Usually this is accomplished by adjusting the pump ramp speed on the soft start and/or variable frequency drive.

It is recommended that the pumps at BPS#1, BPS#2, and BPS#3 be ramped up to full speed in 200 seconds or longer. The pumps at each booster pump station should be started one at a time with at least a 500 second lag between each pump start. Also, the pumps at each booster pump station can be started in any order. The above recommended pump startup times are based on the assumption that three identical pumps will be installed at each booster pump station and should be checked once the design details of each booster pump station are more fully developed.

For this analysis, it was assumed that the pressure control valves at Santiago Creek, Coastal Junction, CM-10 and CM-12 would fully close in about 30 minutes during the booster pump station startup sequence to facilitate the switch between MWD water and the desalination plant product water. In addition, it was assumed that OC-44 A and B would close in 10 minutes and the pressure reducing valves proposed for installation at the connection of the PRC Pipeline to Huntington Beach and at the ICF would modulate in about 10 minutes to maintain the desired set point pressure. The hydraulically operated isolation valve proposed for installation on a bypass around the pressure reducing valve at STA 254+00 on the OC-44 Transmission Main was assumed to open in 20 minutes while the pressure reducing valve was assumed to close on flow reversal in the pipeline. These operating times are preliminary estimates only and should be checked once the design details for the booster pump stations are more fully developed.

Figures 52, 54, 56, 57, 59, 60 and 61 show the predicted maximum and minimum HGL elevations in the proposed PRC Pipeline, OC-44 Transmission Main, EOCF#2, Aufdenkamp Transmission Main, Joint Transmission Main, ICF, OCF Ext., and Coastal Supply Line following startup of the booster pump stations with surge control installed.

For all of the pipelines and transmission mains, the maximum pressures are predicted to not exceed the maximum allowable pressures. Most importantly, the maximum HGL elevations are predicted to not exceed the maximum allowable HGL elevation in the Irvine Cross Feeder and EOCF#2. Also, the maximum HGL elevations are shown to not exceed the set point HGL elevations for the pressure relief valves at STA 254+00 on the OC-44 Transmission Main and STA 1773+82 (Red Lion) on the OCF Ext, which means that these valves will remain closed. The minimum HGL elevations are shown to remain above the crown elevation of all of the pipelines and transmission mains and the vacuum relief valves will remain closed.

Movies of the simulations summarized in Figures 52, 54, 56 and 59 are provided on the CDROM enclosed as Appendix A..

Figures 53, 55, 58 and 62 depict the predicted pressure head histories at BPS#1, the PRC Pipeline Interconnection to Huntington Beach, the OC-44 pressure relief valve, the vacuum relief valve at STA 453+08 on the OC-44 Transmission Main, the suction and discharge sides of BPS#2, the vacuum relief valve at STA 1194+94 on EOCF#2, the OC-39 turn out from EOCF#2, the suction and discharge sides of BPS#3, the vacuum relief valves at the high points on the ICF, Aufdenkamp and Joint Transmission Mains, the pressure relief valve on the OCF Ext. (Red Lion) and the vacuum relief valve at STA 2048+82 on the OCF Ext. following startup of the booster pump stations with surge control installed.

Not shown in these figures is that water is predicted to flow into the San Joaquin Reservoir via the air gap at that location when the booster pump stations are ramped up to full speed to facilitate switching between MWD water and the desalination plant product water. Although it is permissible to spill some water into the San Joaquin Reservoir, it would be desirable to prevent such a loss of water from the system. Therefore, once the design details for the booster pump stations are more fully developed it is recommended that additional surge analyses be performed to refine the ramp times for the pumps at the booster pump stations to prevent spillage into the San Joaquin Reservoir.

A separate startup analysis was also performed for BPS#4 based on Scenario No. 3 in Section 5. For this analysis, it was assumed that BPS#1, BPS#2 and BPS#3 were operating prior to starting the pumps at BPS#4.

It is recommended that the pumps at BPS#4 be ramped up to full speed in 200 seconds or longer. The pumps at BPS#4 should be started one at a time with at least a 200 second lag between each pump start. The above recommended pump startup time is based on the assumption that two identical pumps will be installed at BPS#4 and should be checked once the design details of this booster pump station are more fully developed.

Figures 63 and 64 show the predicted maximum and minimum HGL elevations in WOCWBF#2 and WOCWBF#1, respectively, after BPS#4 startup. The maximum pressures are predicted to not exceed the maximum allowable pressures for all of the analyzed pipelines and transmission mains, including WOCWBF#2 and WOCWBF#1. Although Figures 63 and 64 show that the maximum HGL elevations are predicted to exceed the steady state HGL elevations in WOCWBF#2 and WOCWBF#1 following pump startup at BPS#4, the pressure relief valves installed on these pipelines are predicted to remain closed. These figures show that the minimum HGL elevation is predicted to remain above the crown elevation of the pipelines. Figure 65 depicts the predicted pressure head histories at the vacuum relief valve at the high point on WOCWBF#2, and the suction and discharge sides of BPS#4.

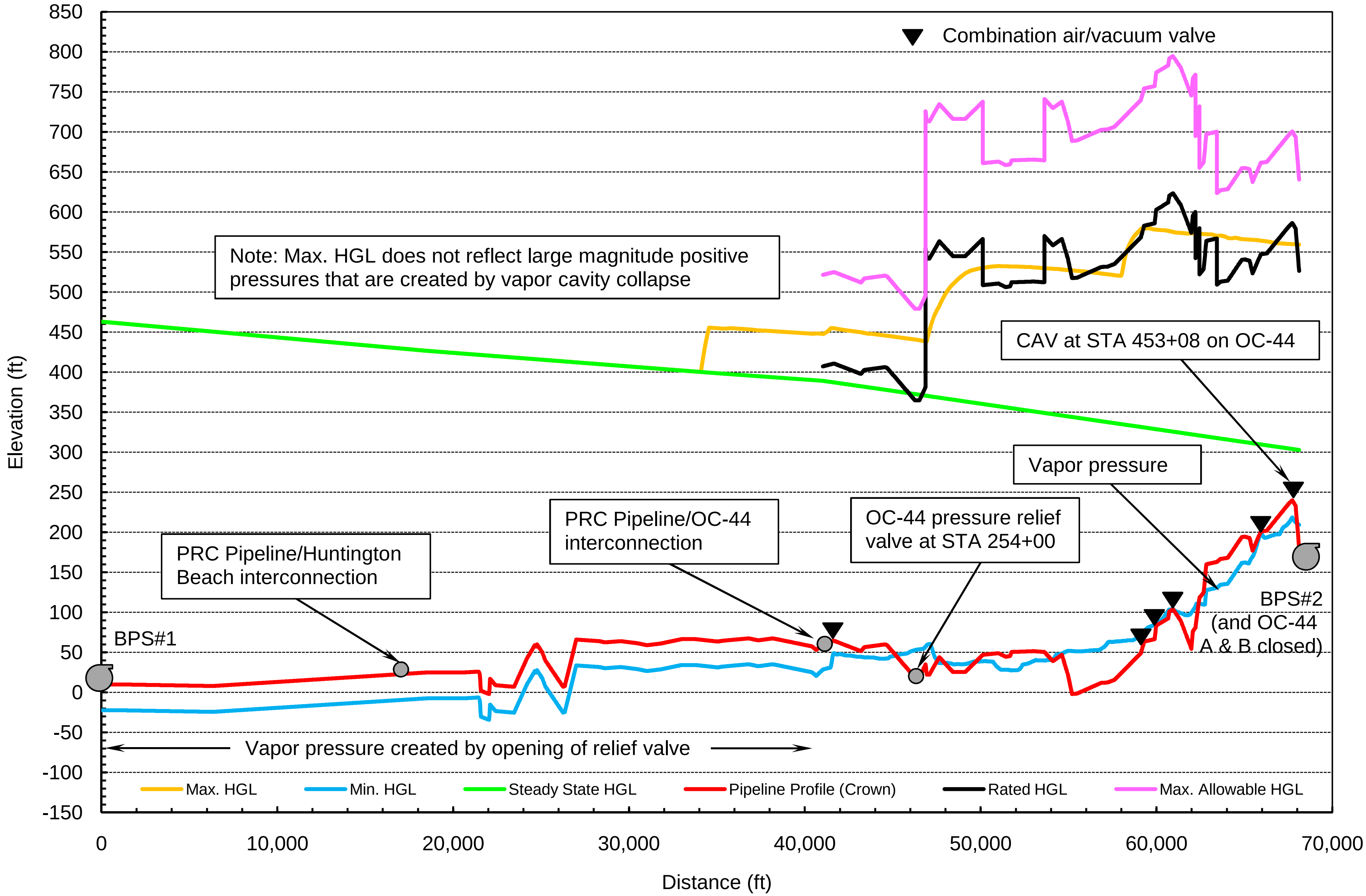

Figure 2: HGL elevations in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

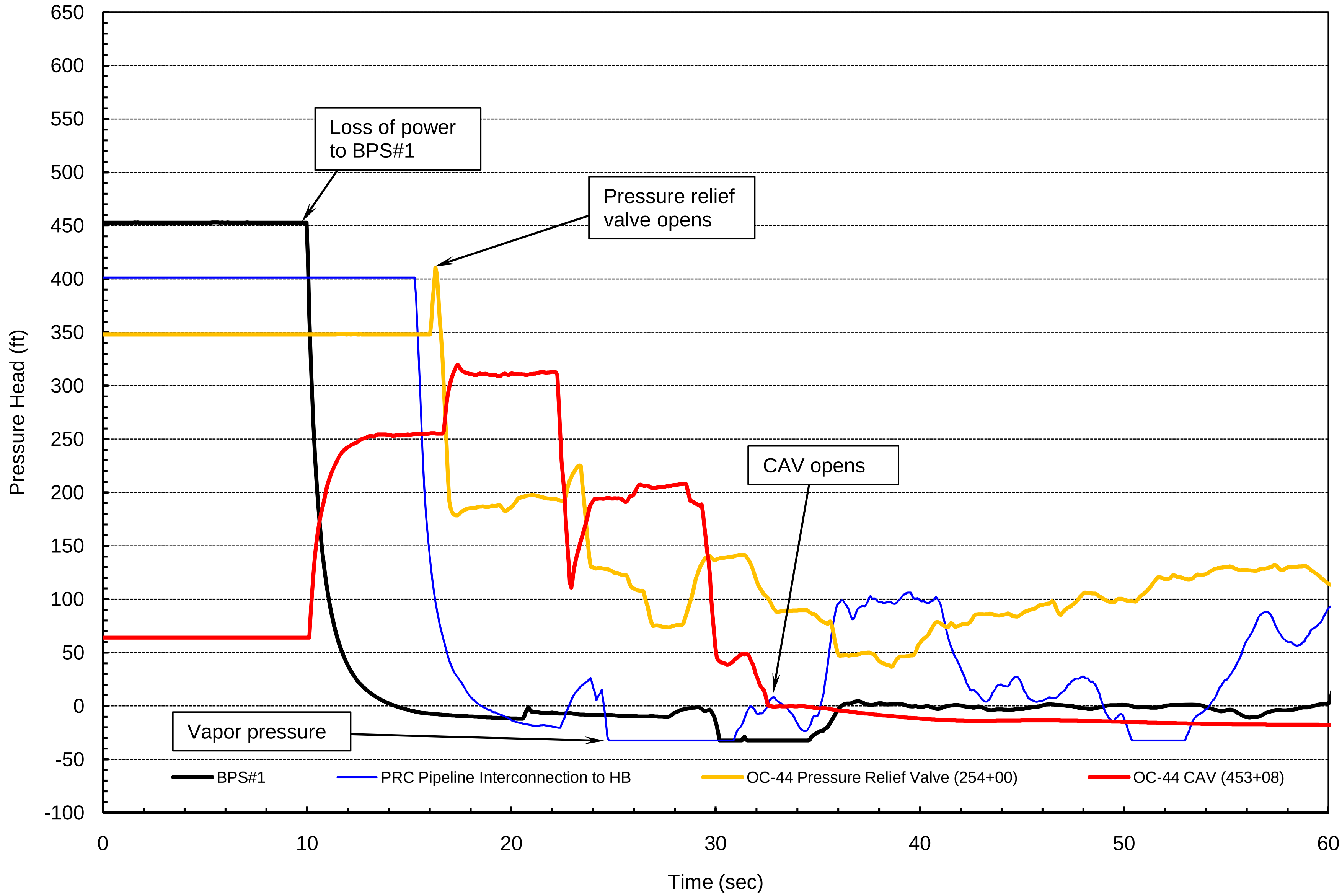

Figure 3: Pressure head records in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

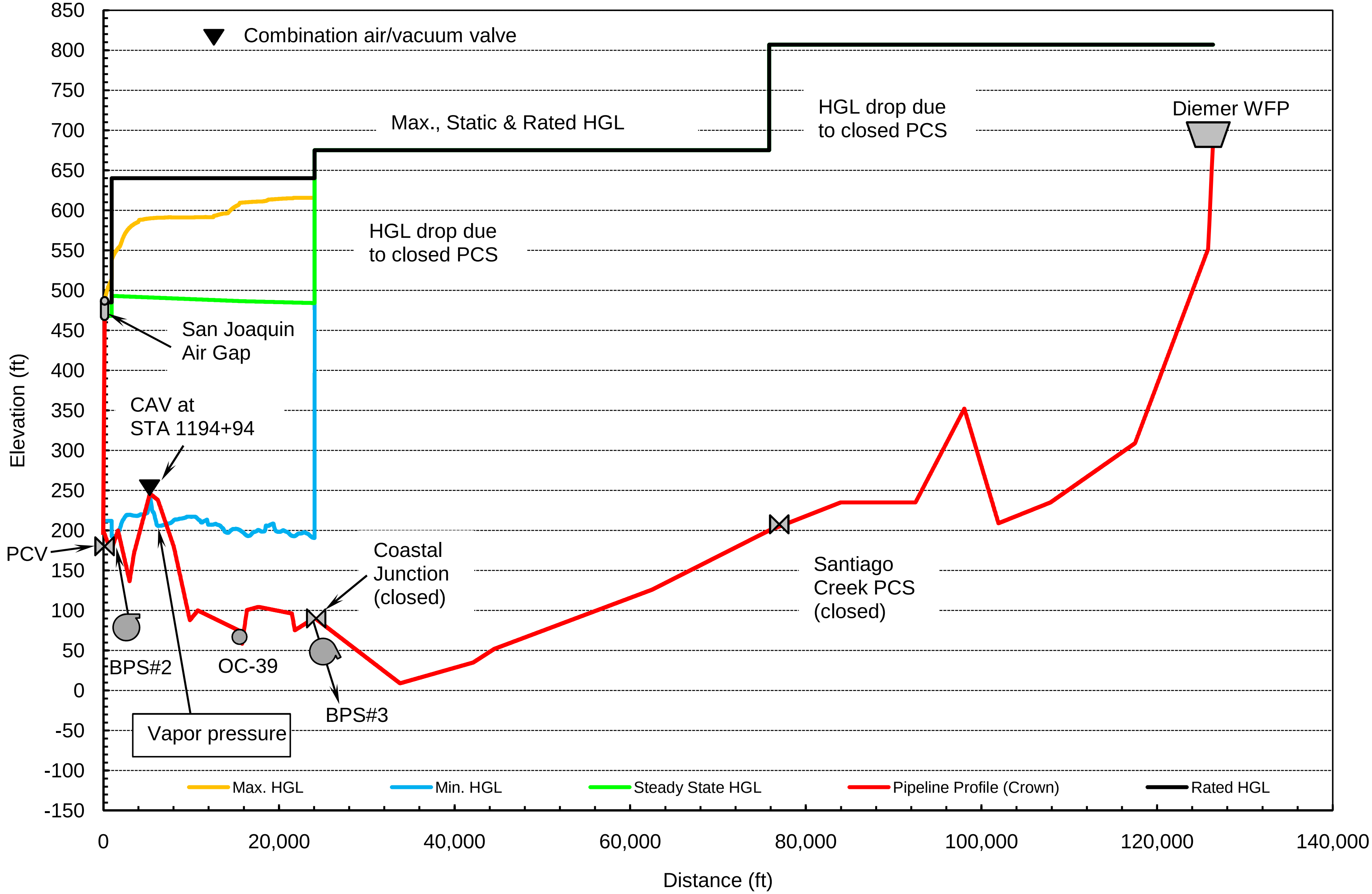

Figure 4: HGL elevations in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

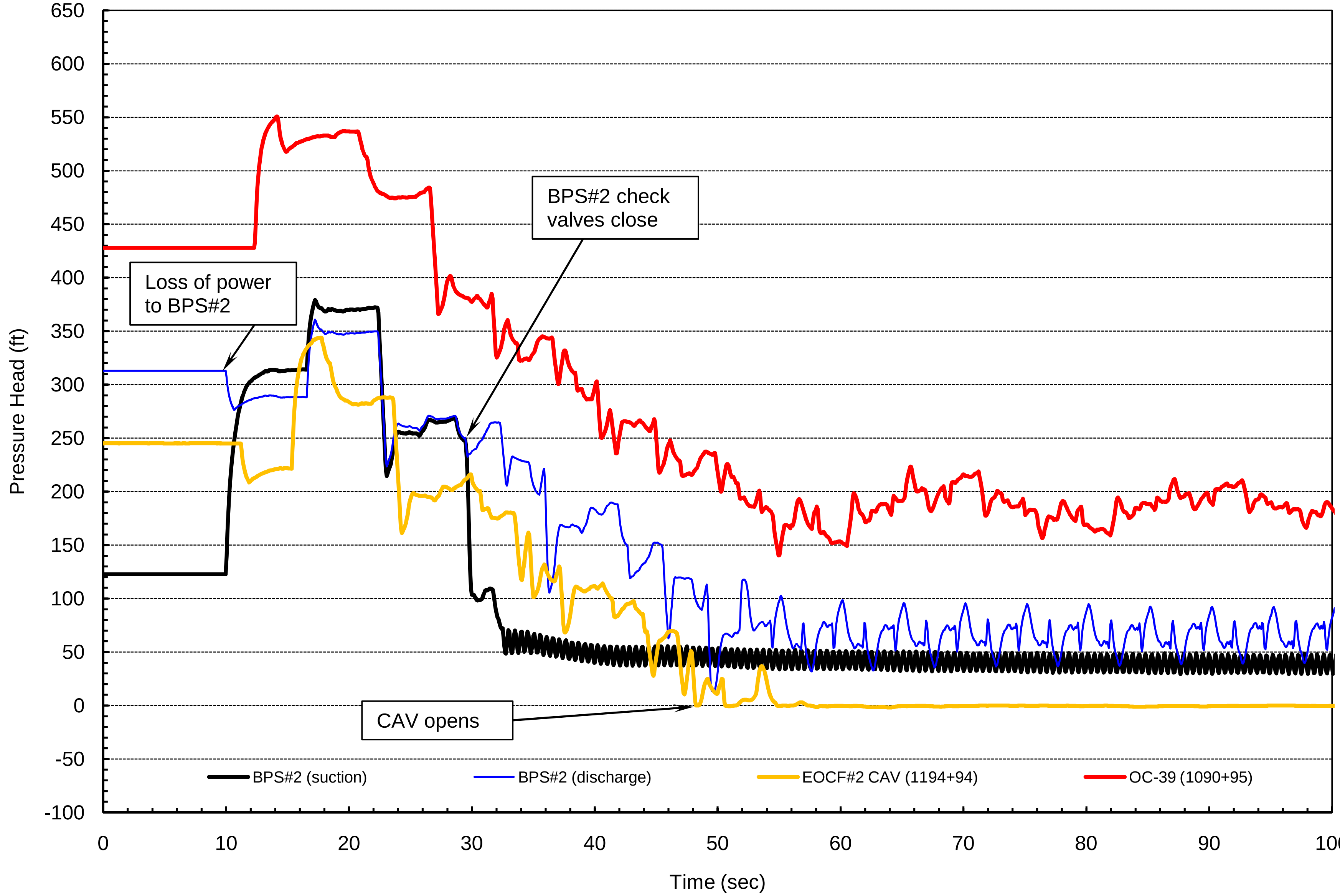

Figure 5: Pressure head records in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

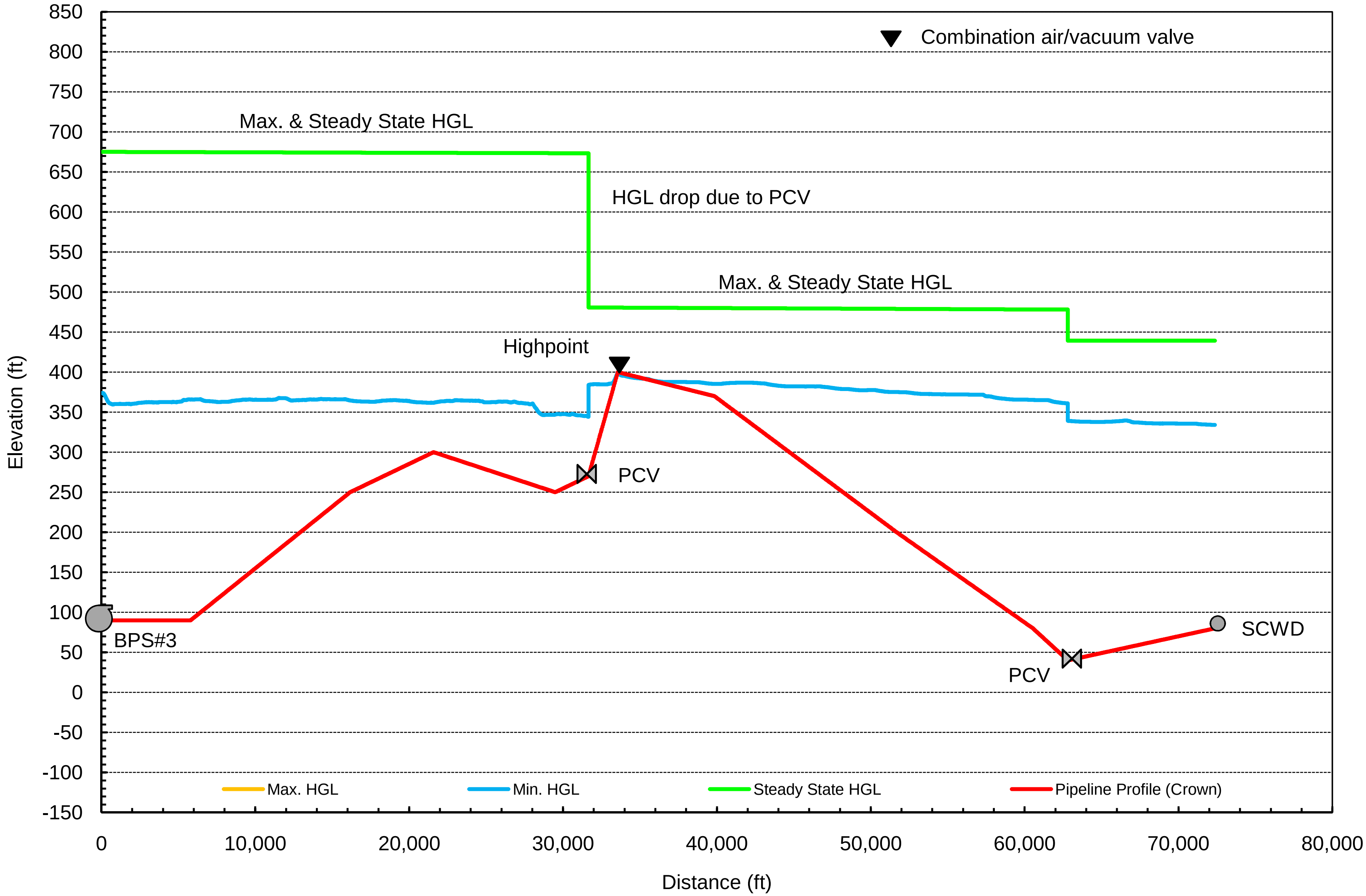

Figure 6: HGL elevations in Path C (Aufdenkamp TM) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

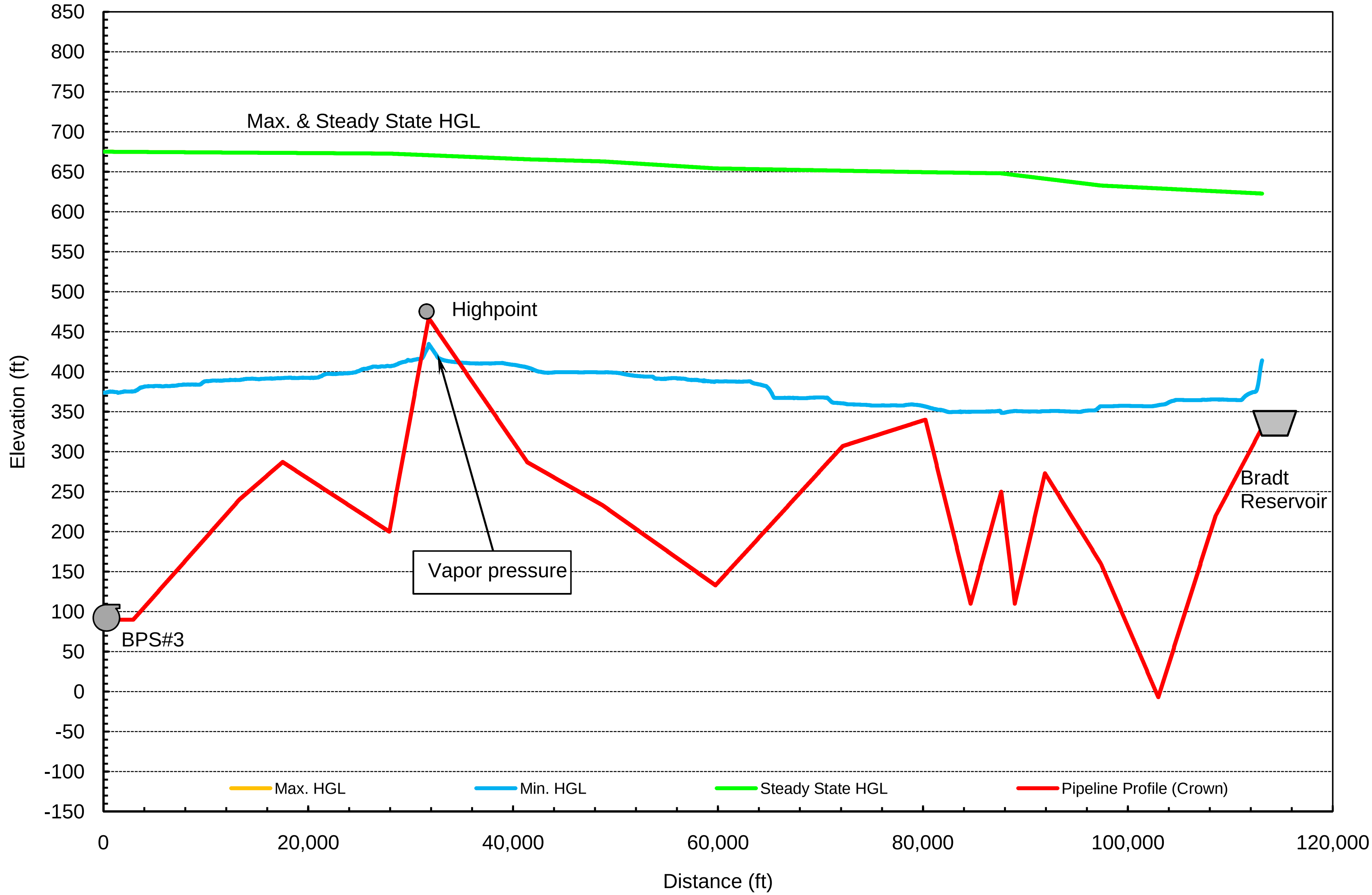

Figure 7: HGL elevations in Path D (Joint TM) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

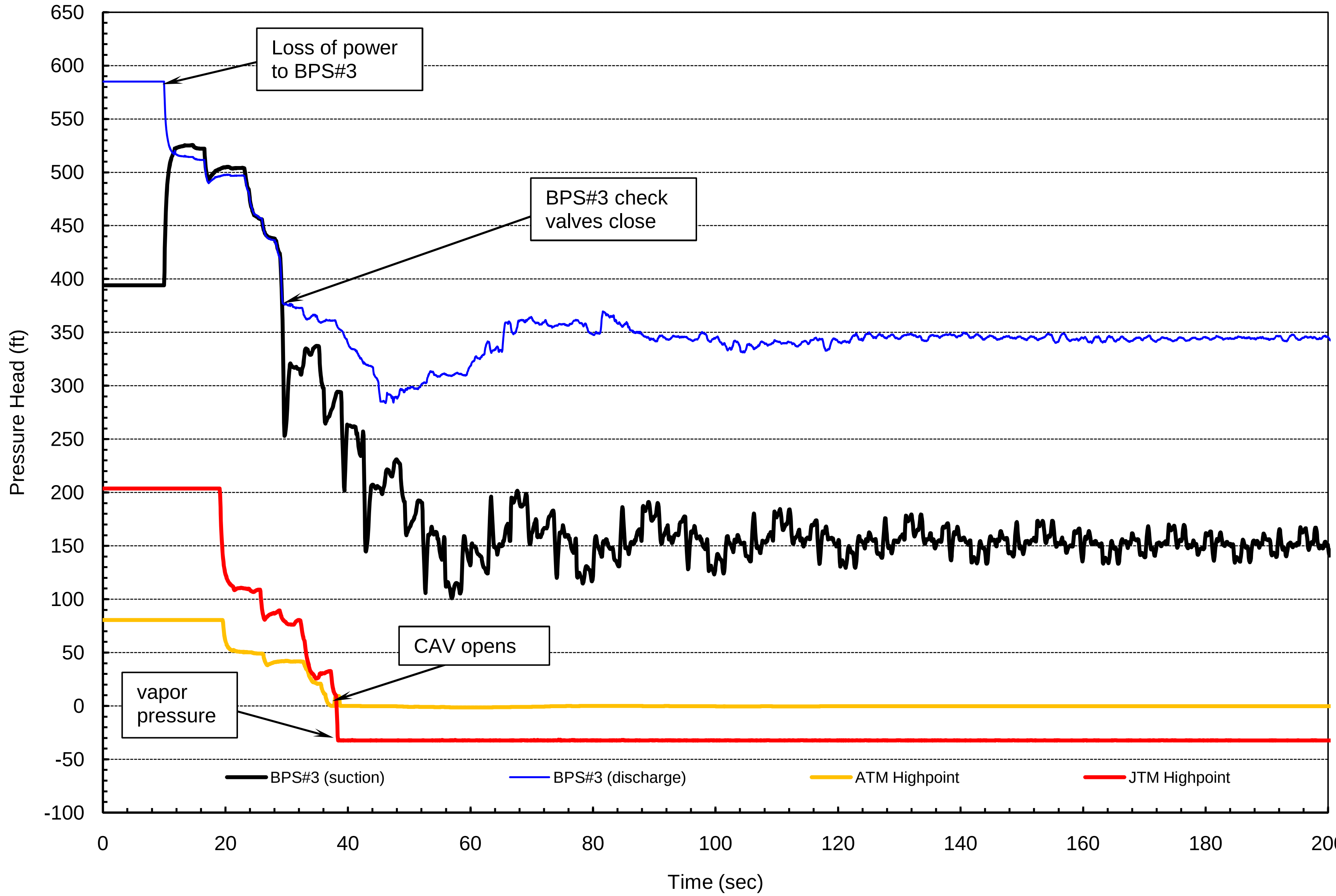

Figure 8: Pressure head records in Paths C and D (Aufdenkamp and Joint TMs) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

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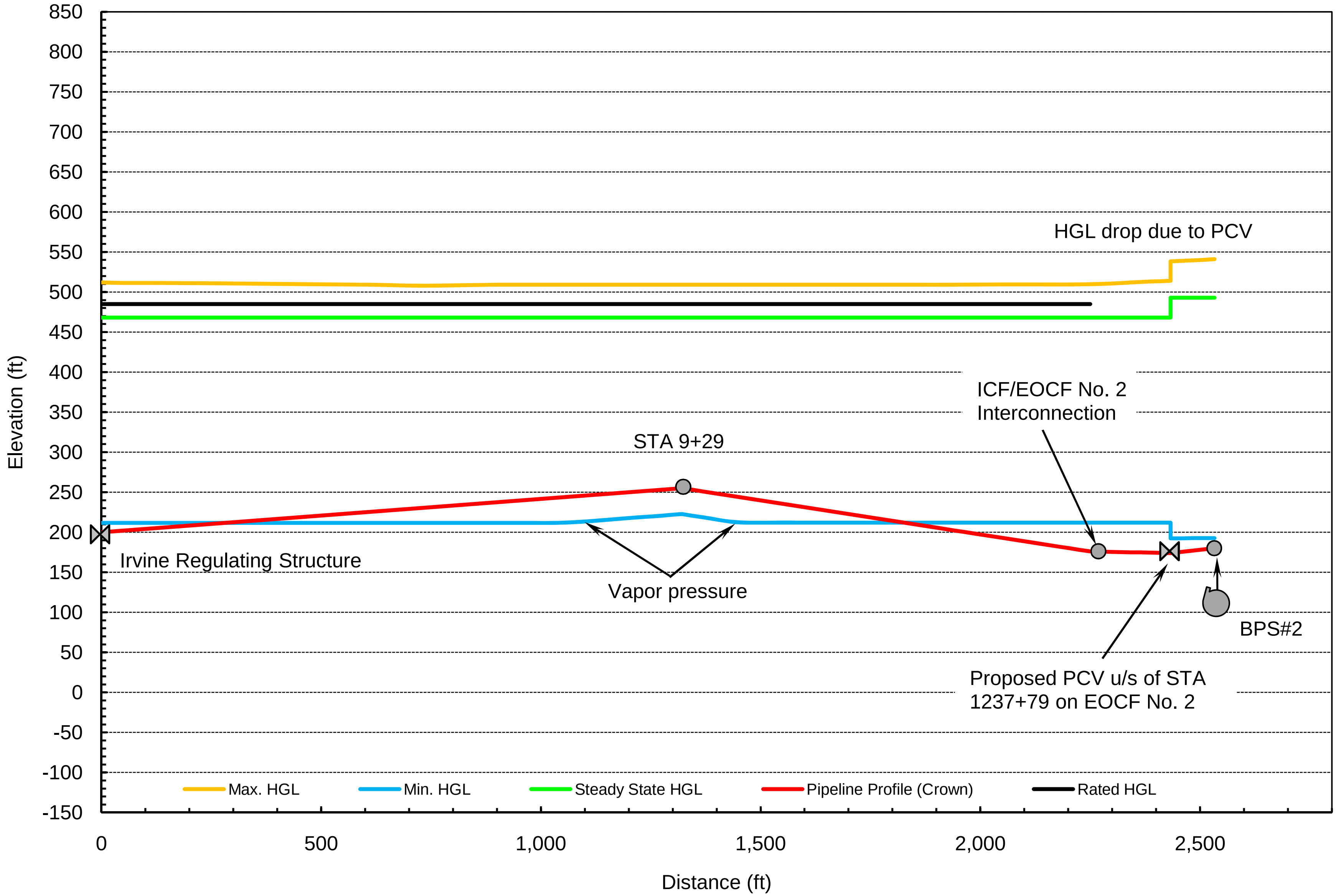

Figure 9: HGL elevations in Path E (Irvine Cross Feeder) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

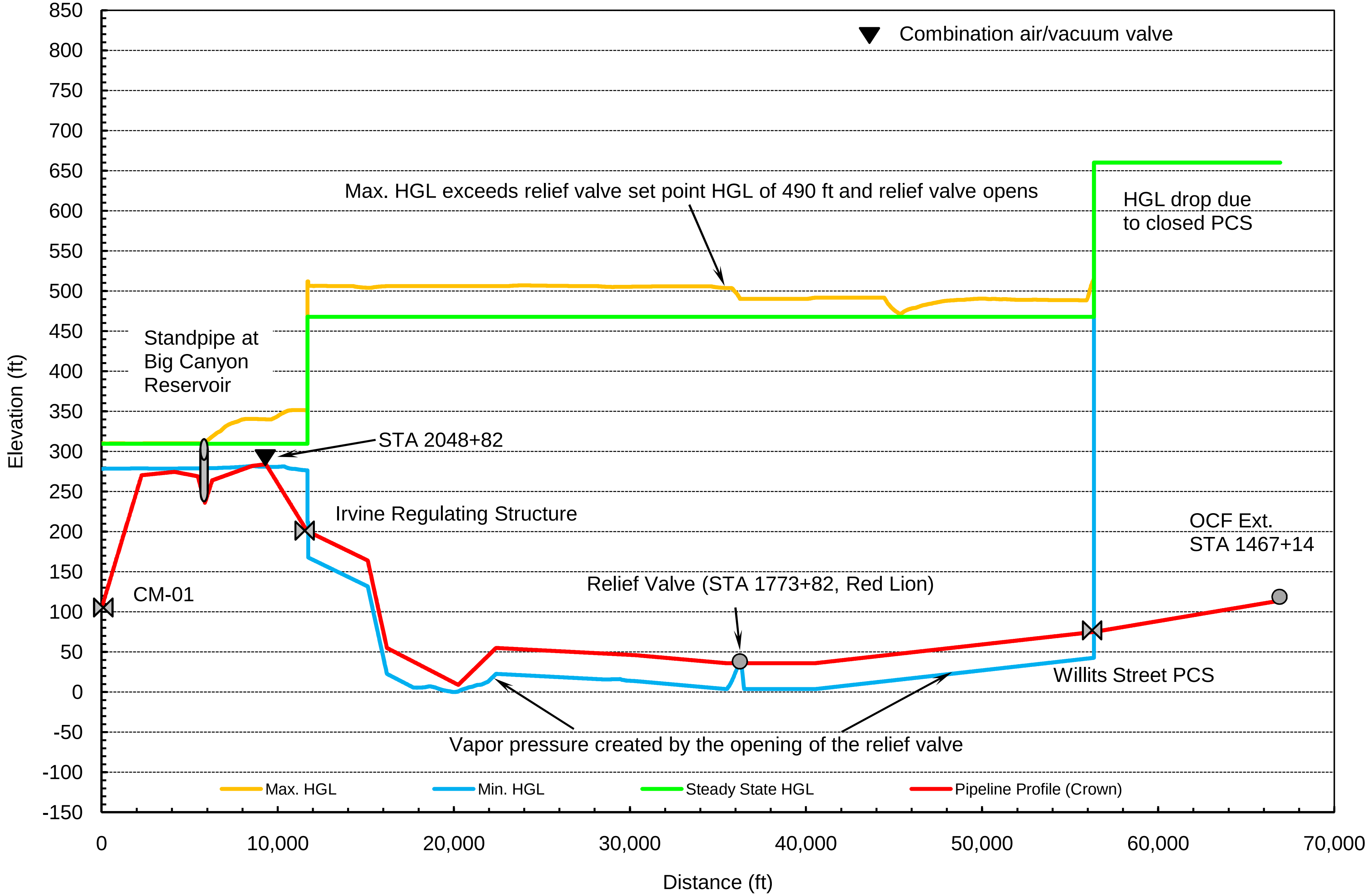

Figure 10: HGL elevations in Path F (OCF Ext.) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

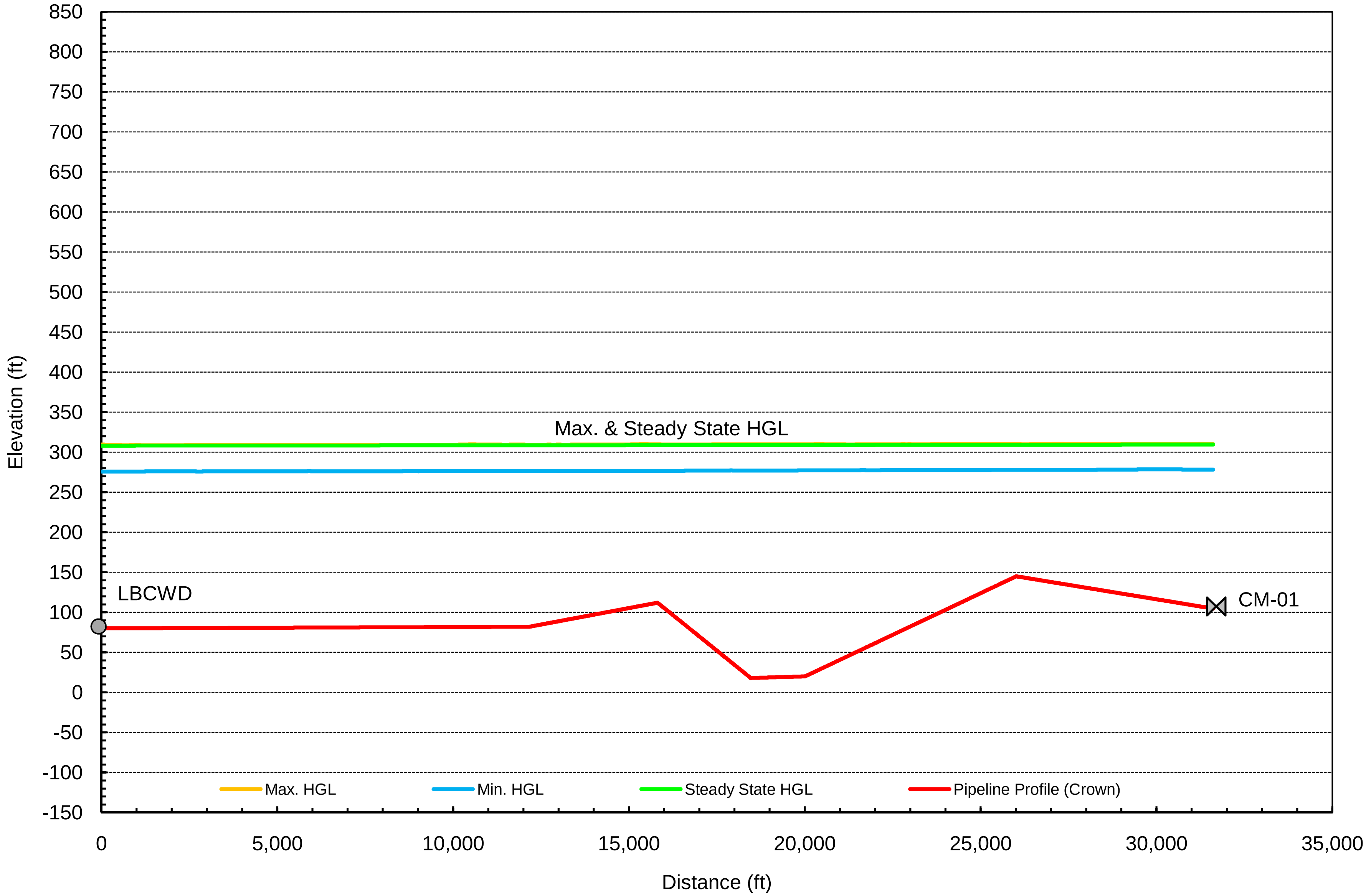

Figure 11: HGL elevations in Path G (Coastal Supply Line) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

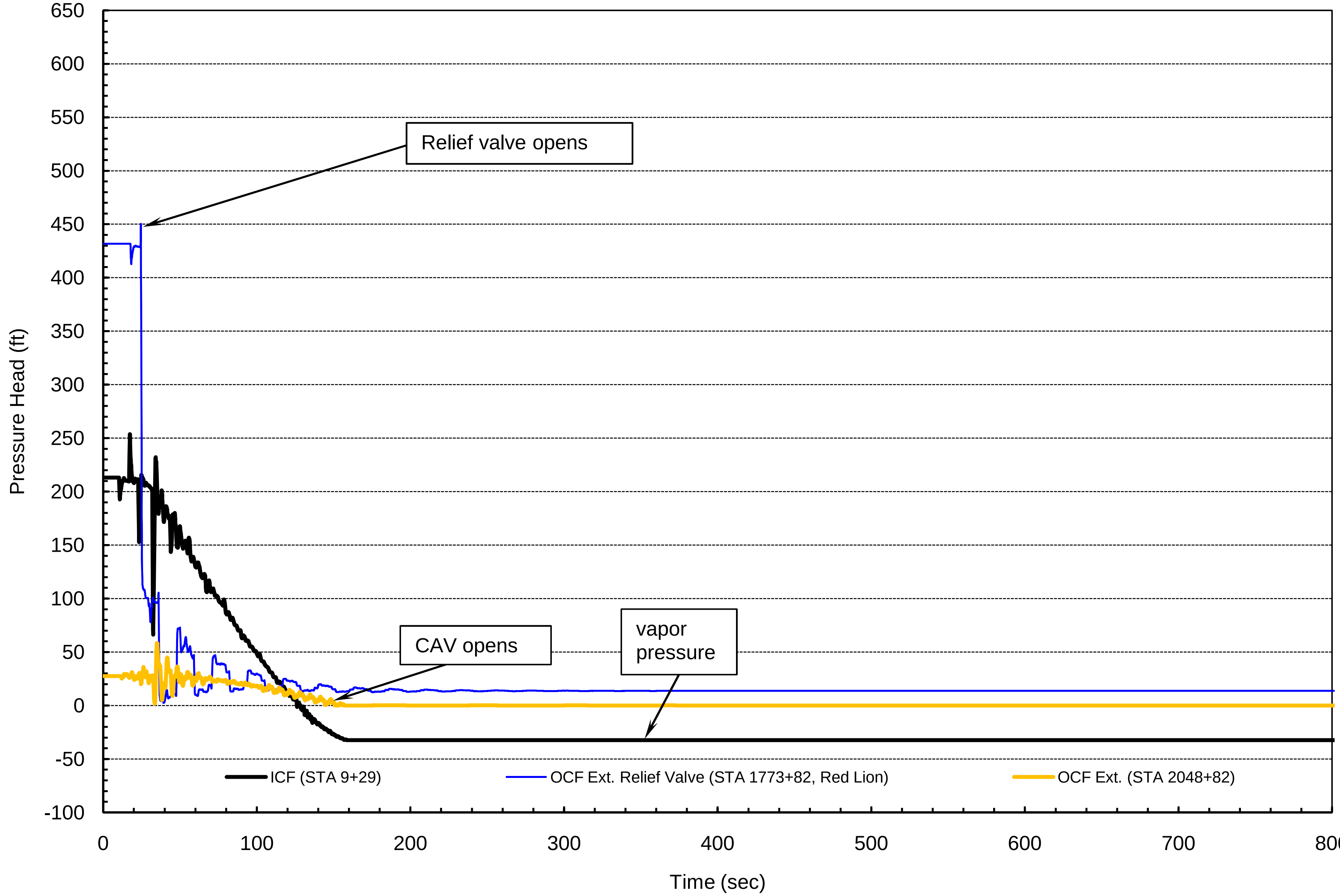

Figure 12: Pressure head records in Paths E and F (ICF and OCF Ext.) following loss of power to booster pump stations under Operating Scenario 1 without surge protection

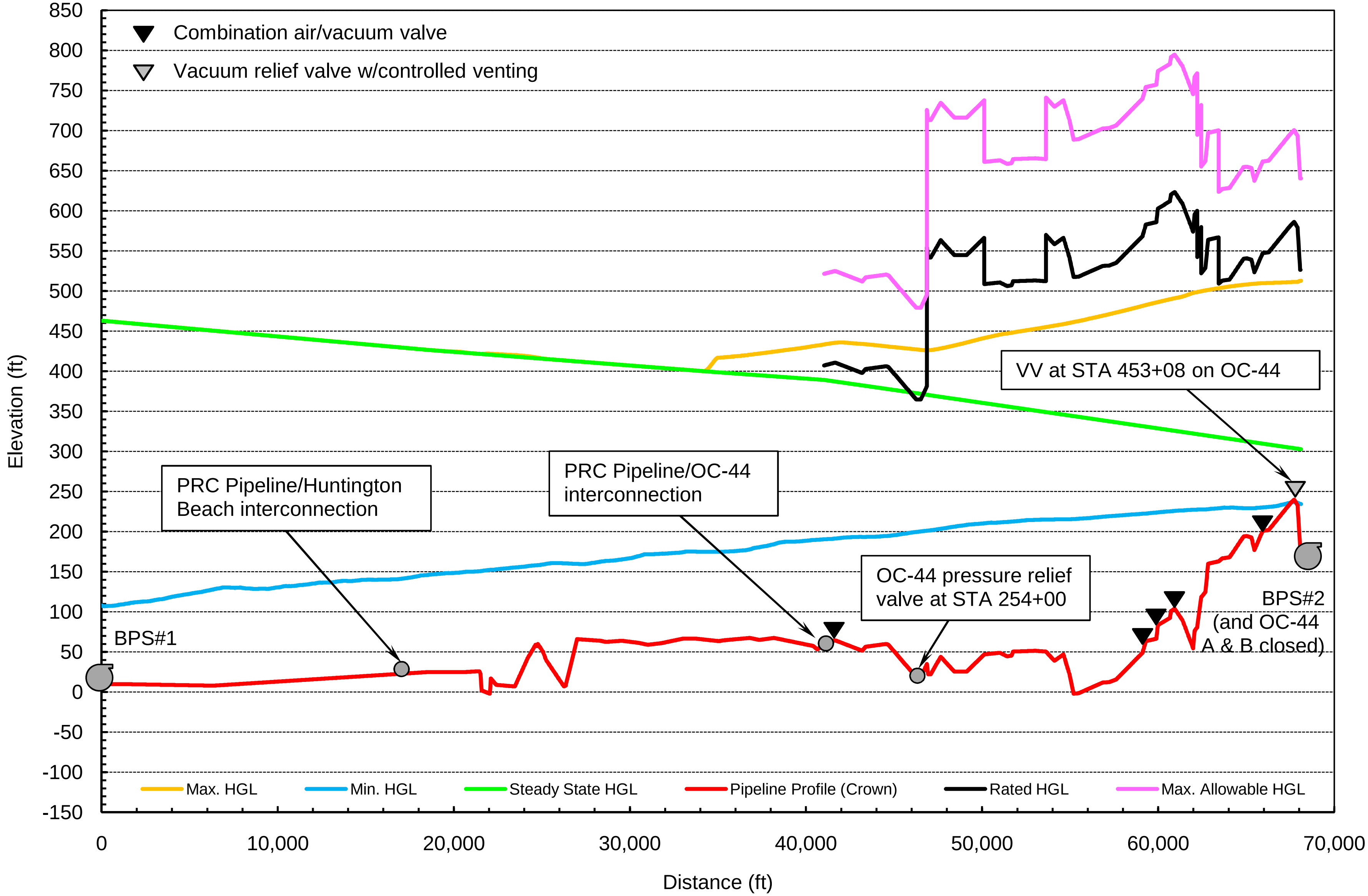

Figure 13: HGL elevations in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

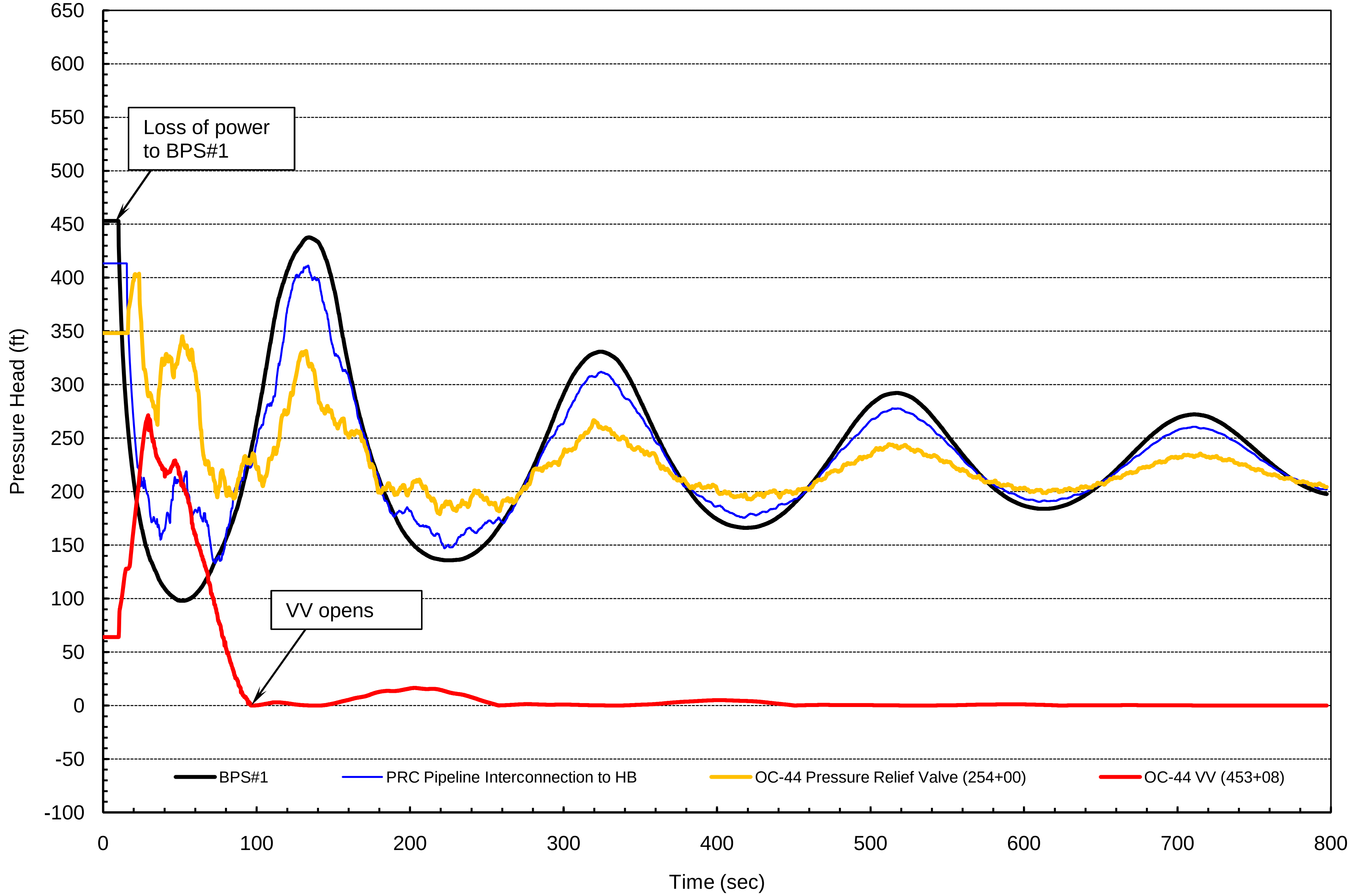

Figure 14: Pressure head records in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

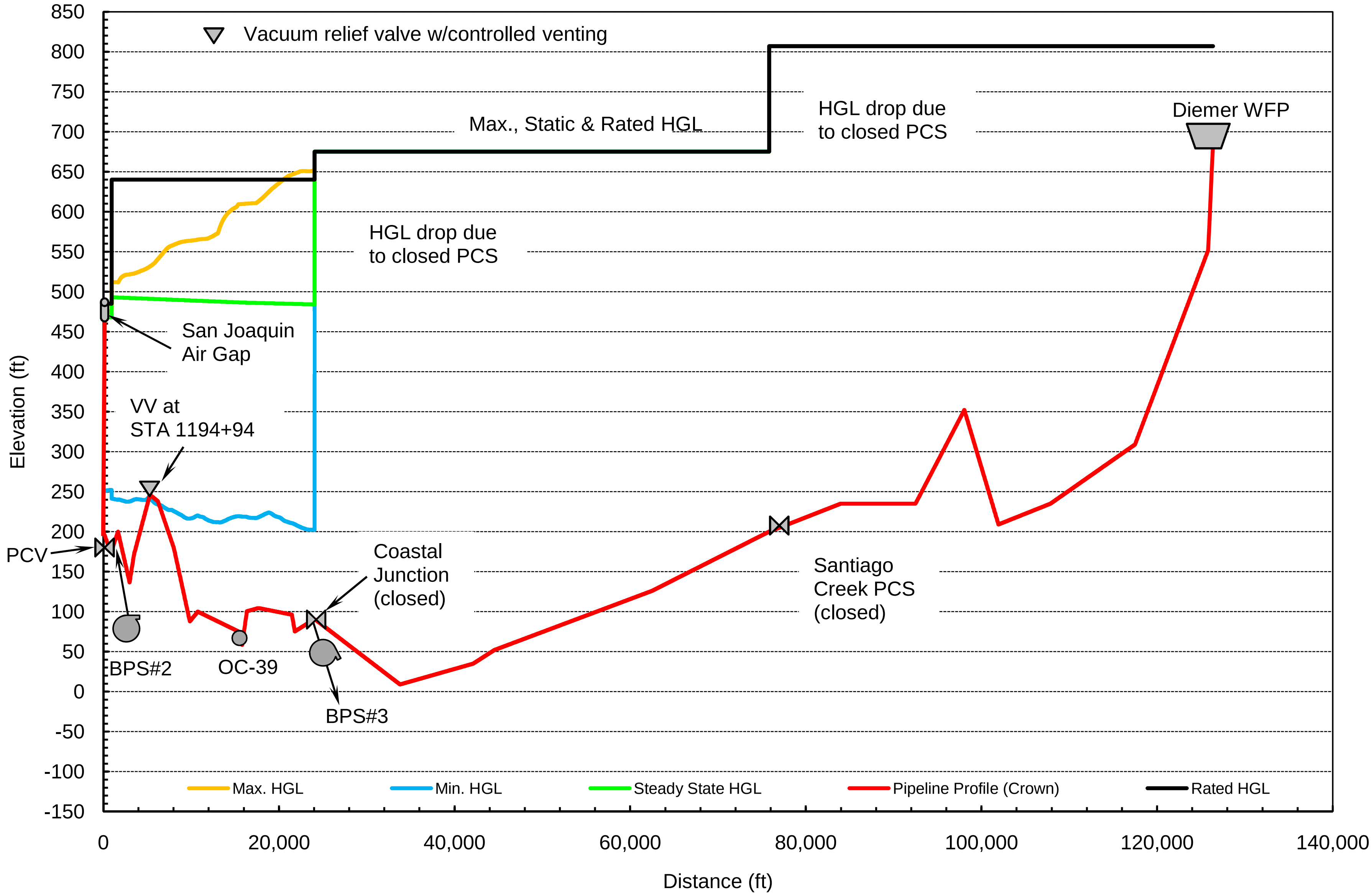

Figure 15: HGL elevations in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

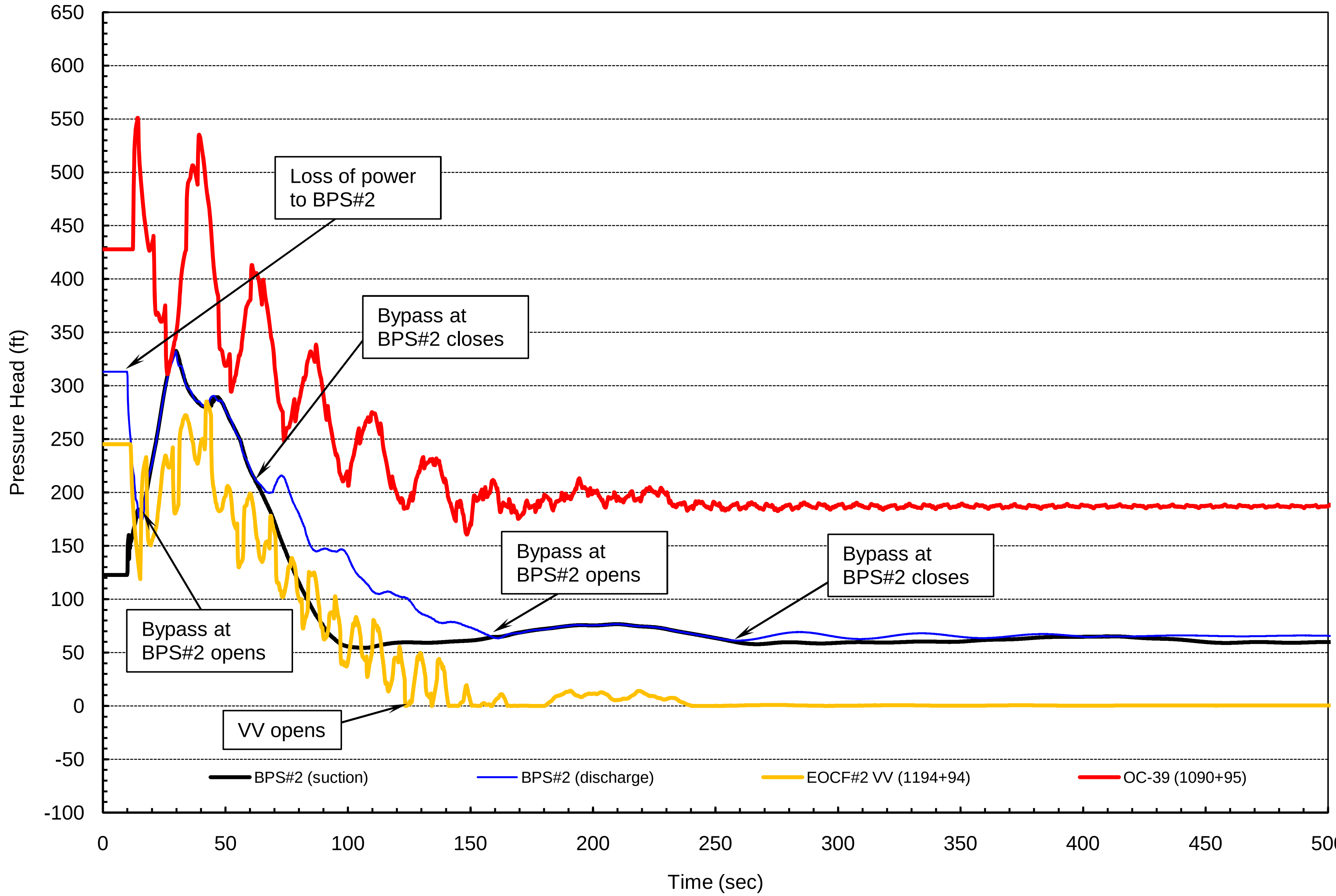

Figure 16: Pressure head records in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

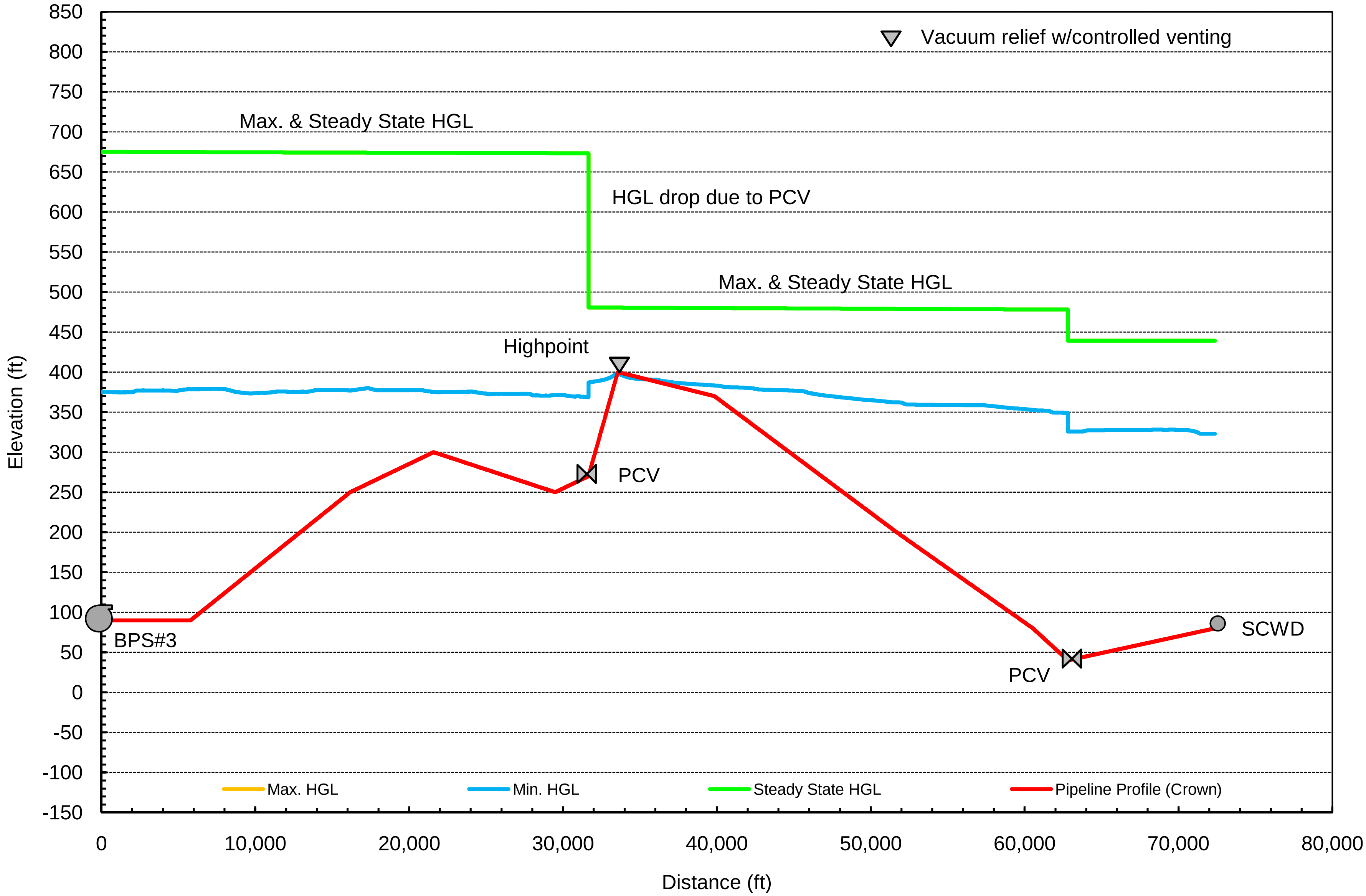

Figure 17: HGL elevations in Path C (Aufdenkamp TM) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

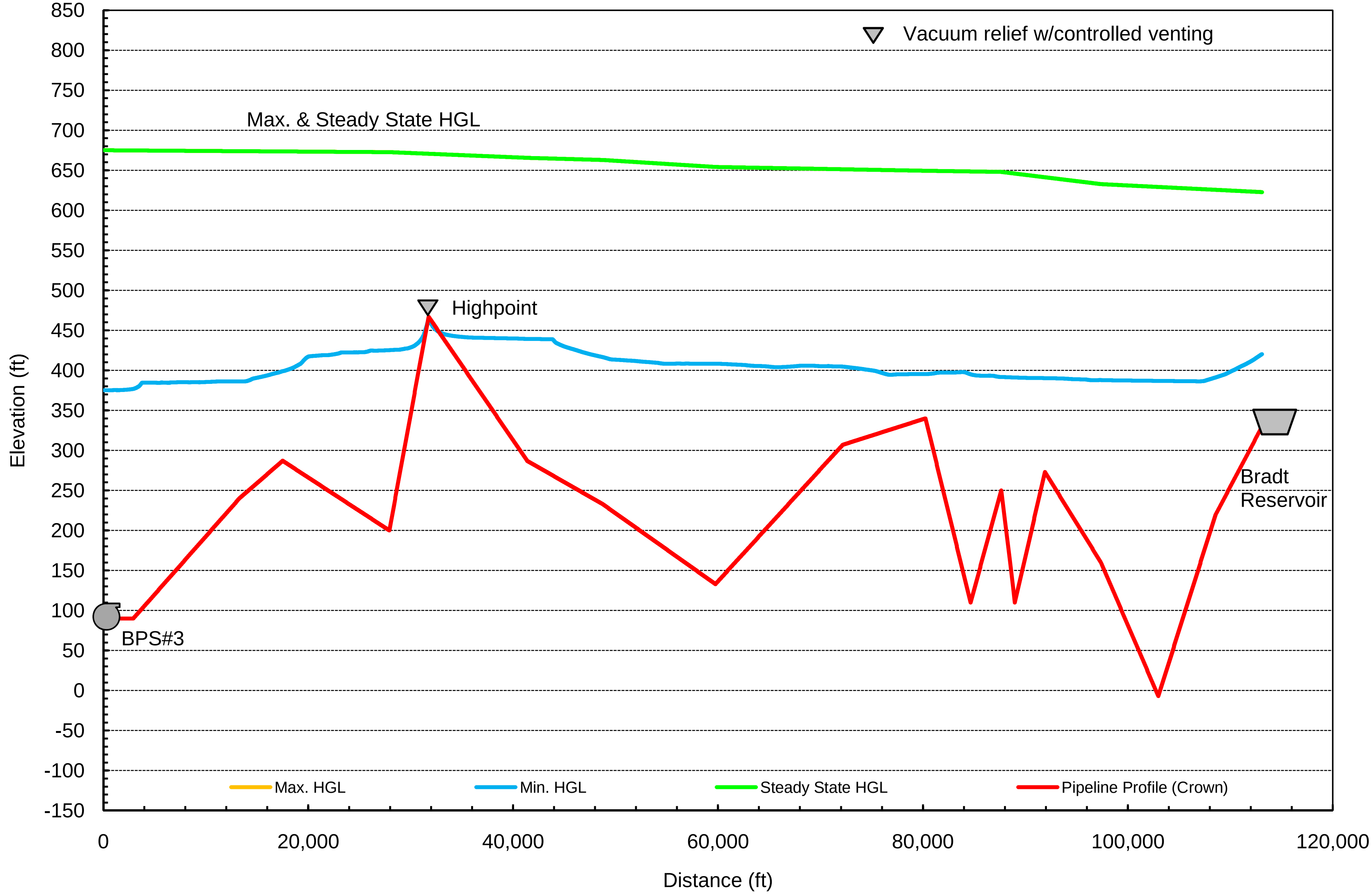

Figure 18: HGL elevations in Path D (Joint TM) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

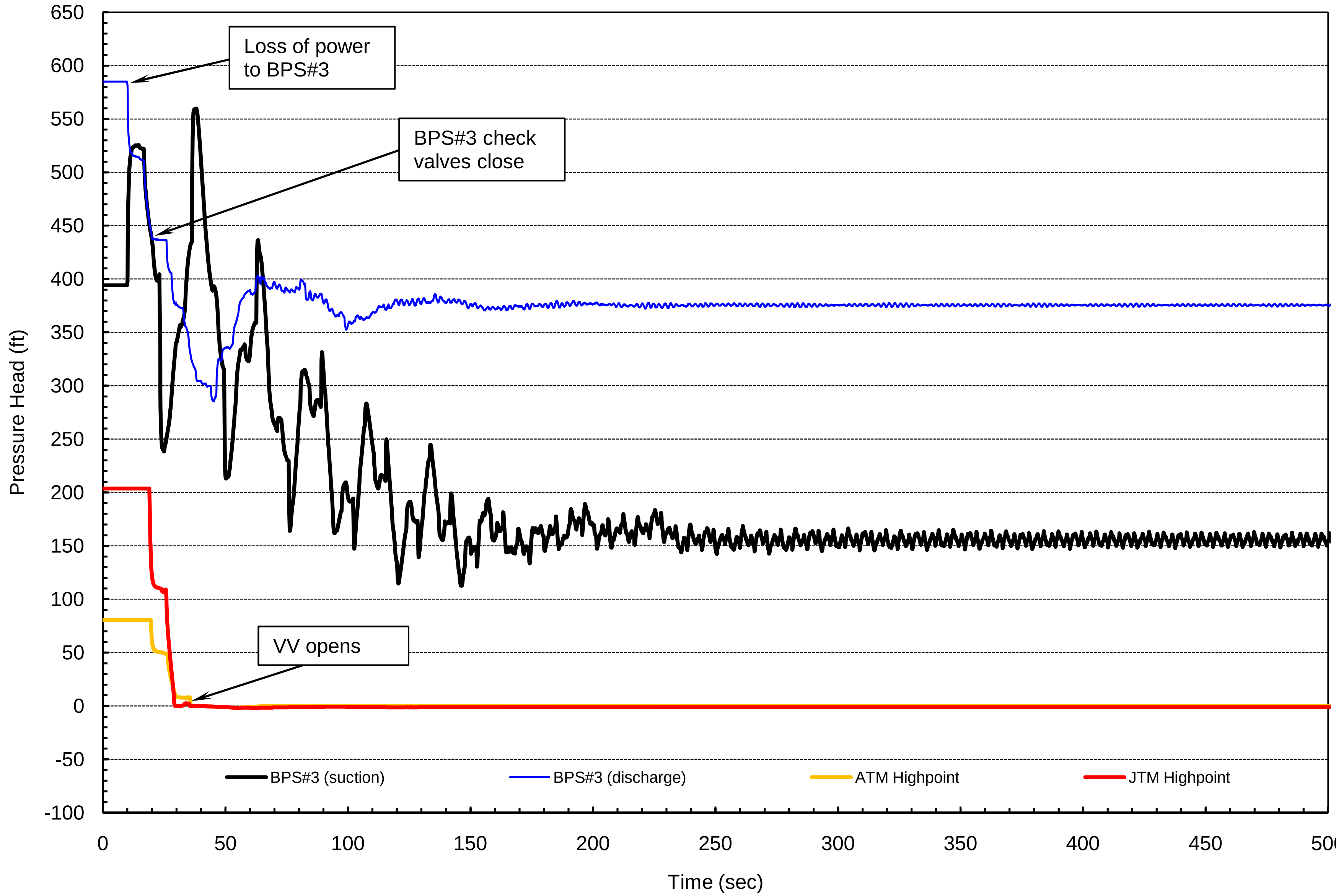

Figure 19: Pressure head records in Paths C and D (Aufdenkamp and Joint TMs) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

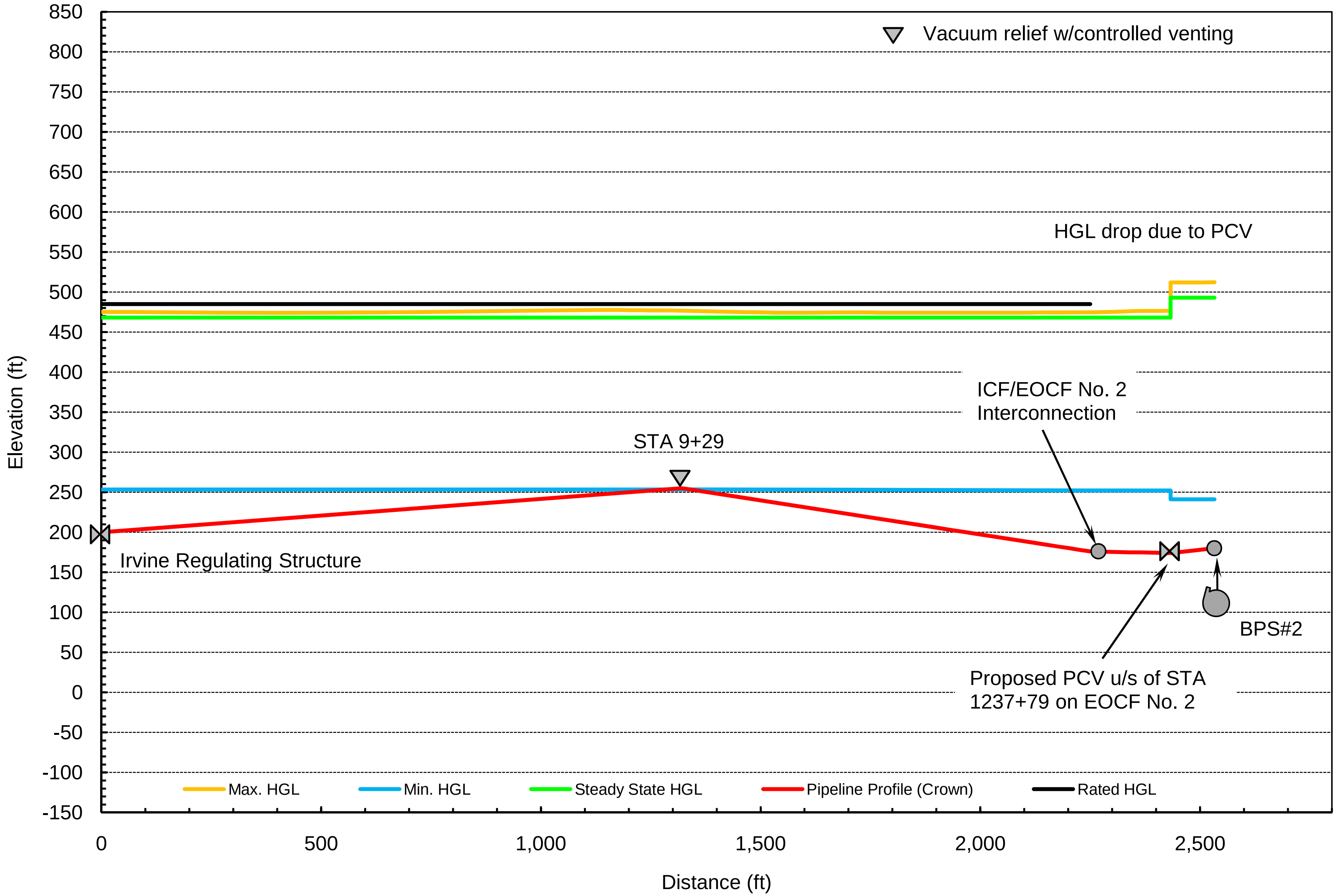

Figure 20: HGL elevations in Path E (Irvine Cross Feeder) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

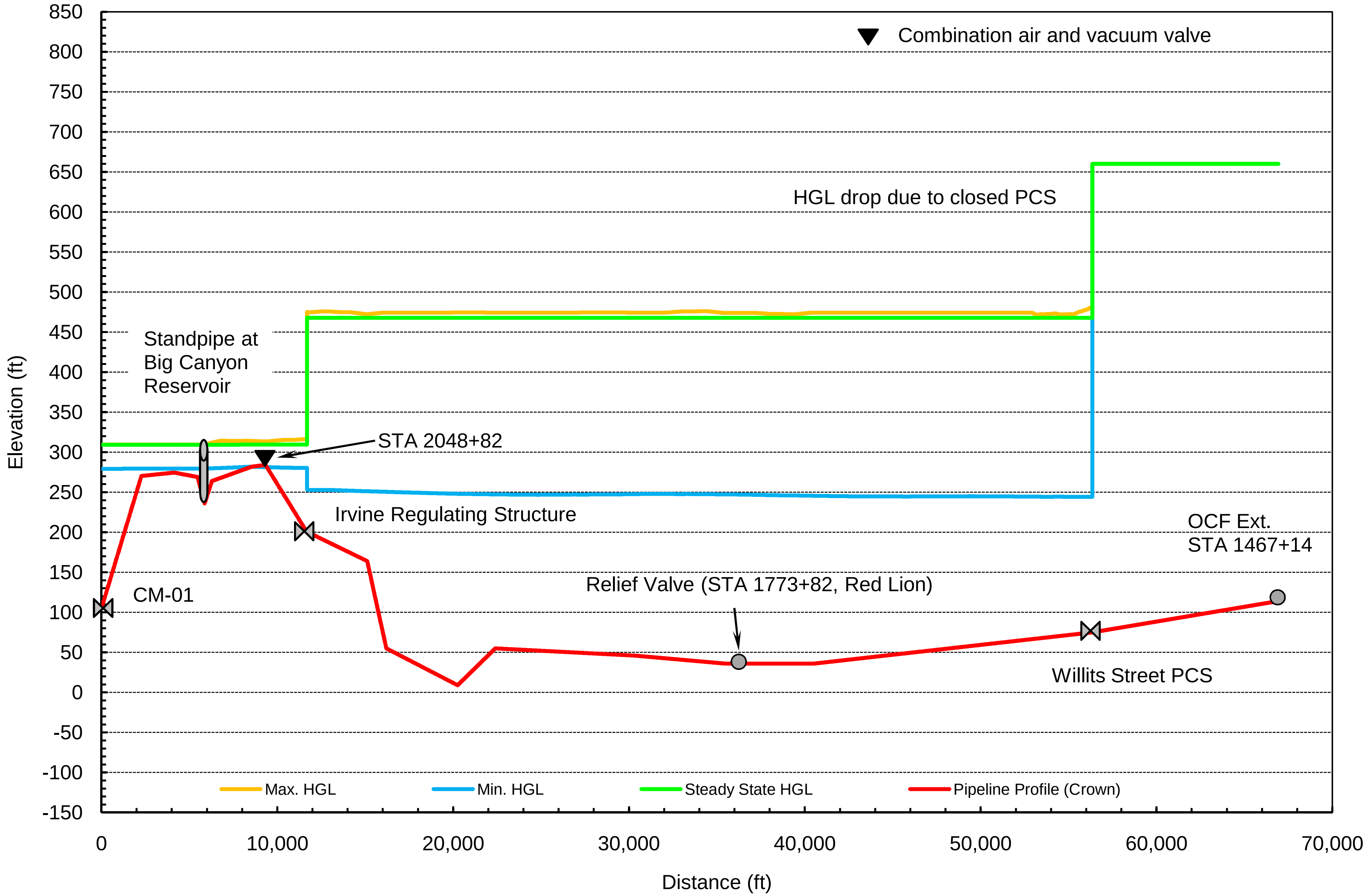

Figure 21: HGL elevations in Path F (OCF Ext.) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

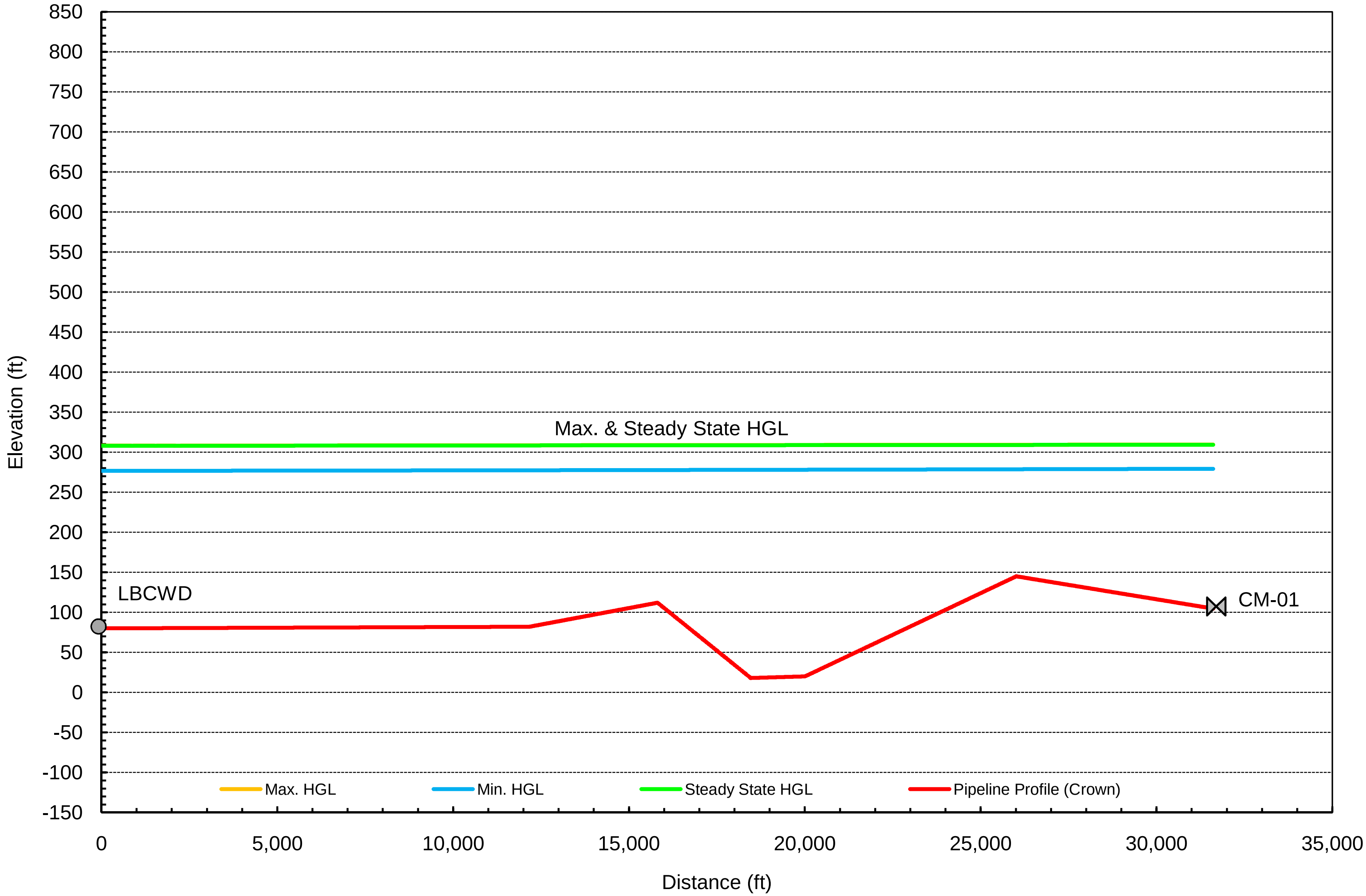

Figure 22: HGL elevations in Path G (Coastal Supply Line) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

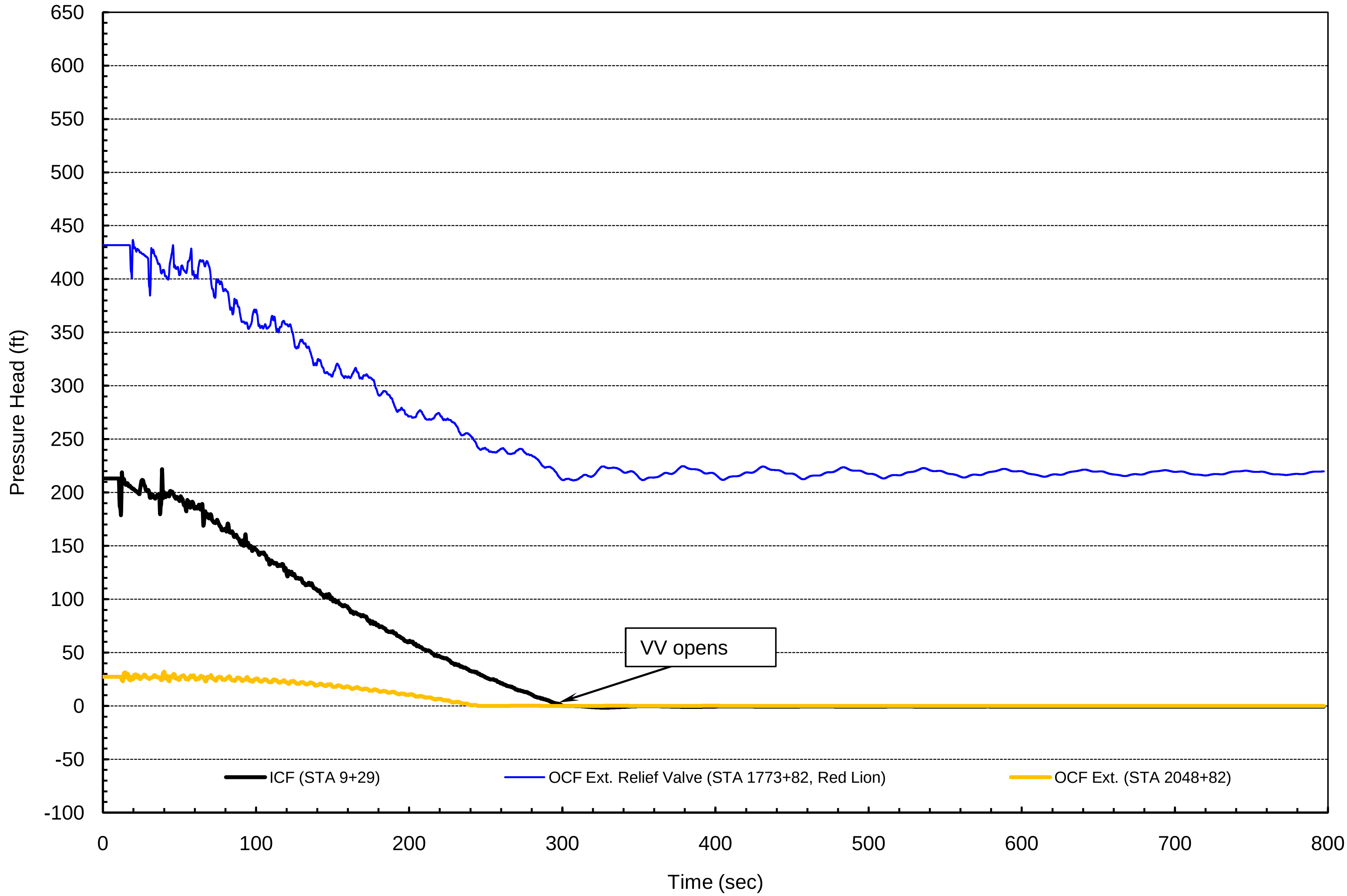

Figure 23: Pressure head records in Paths E and F (ICF and OCF Ext.) following loss of power to booster pump stations under Operating Scenario 1 with surge protection

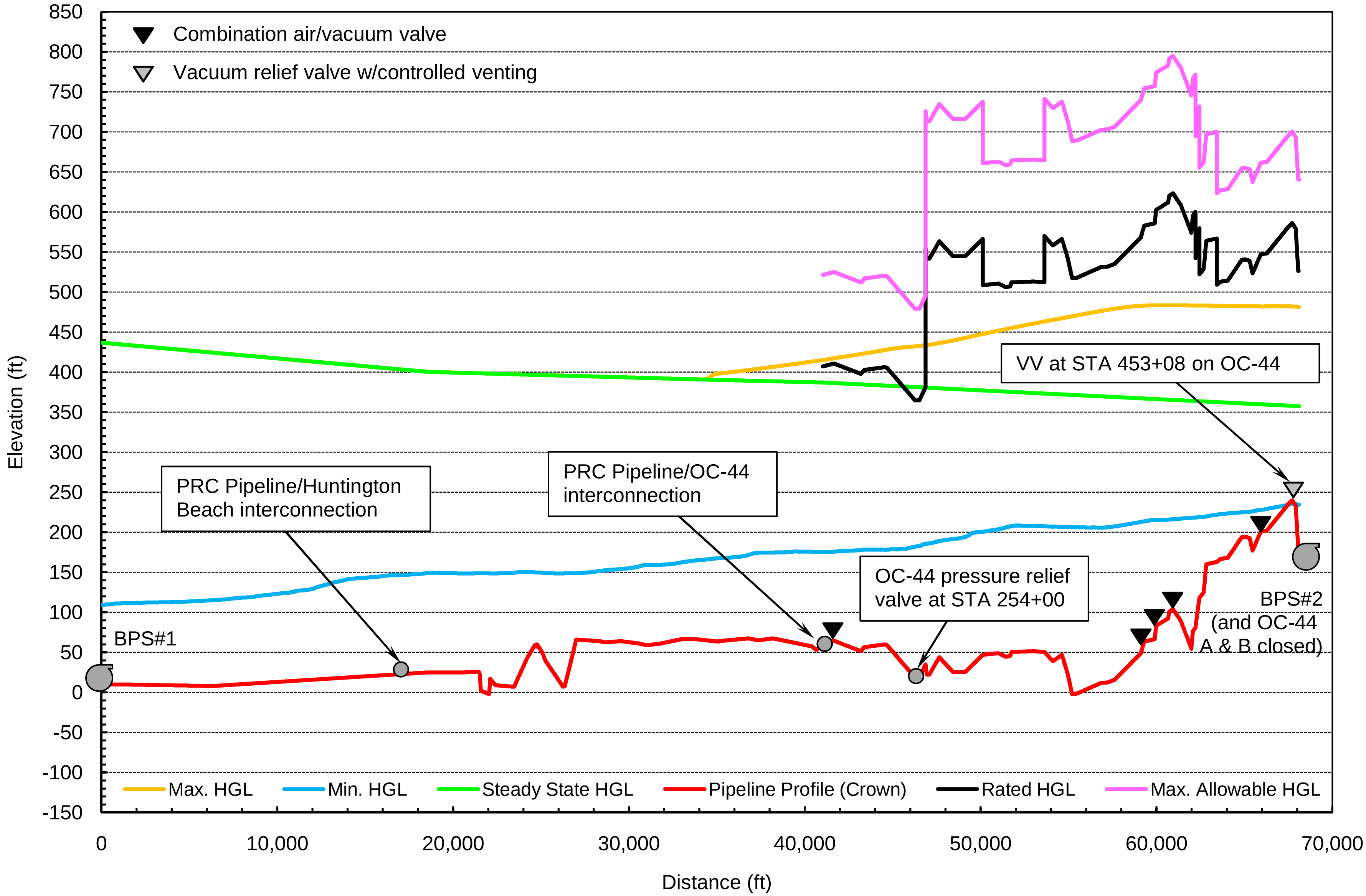

Figure 24: HGL elevations in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

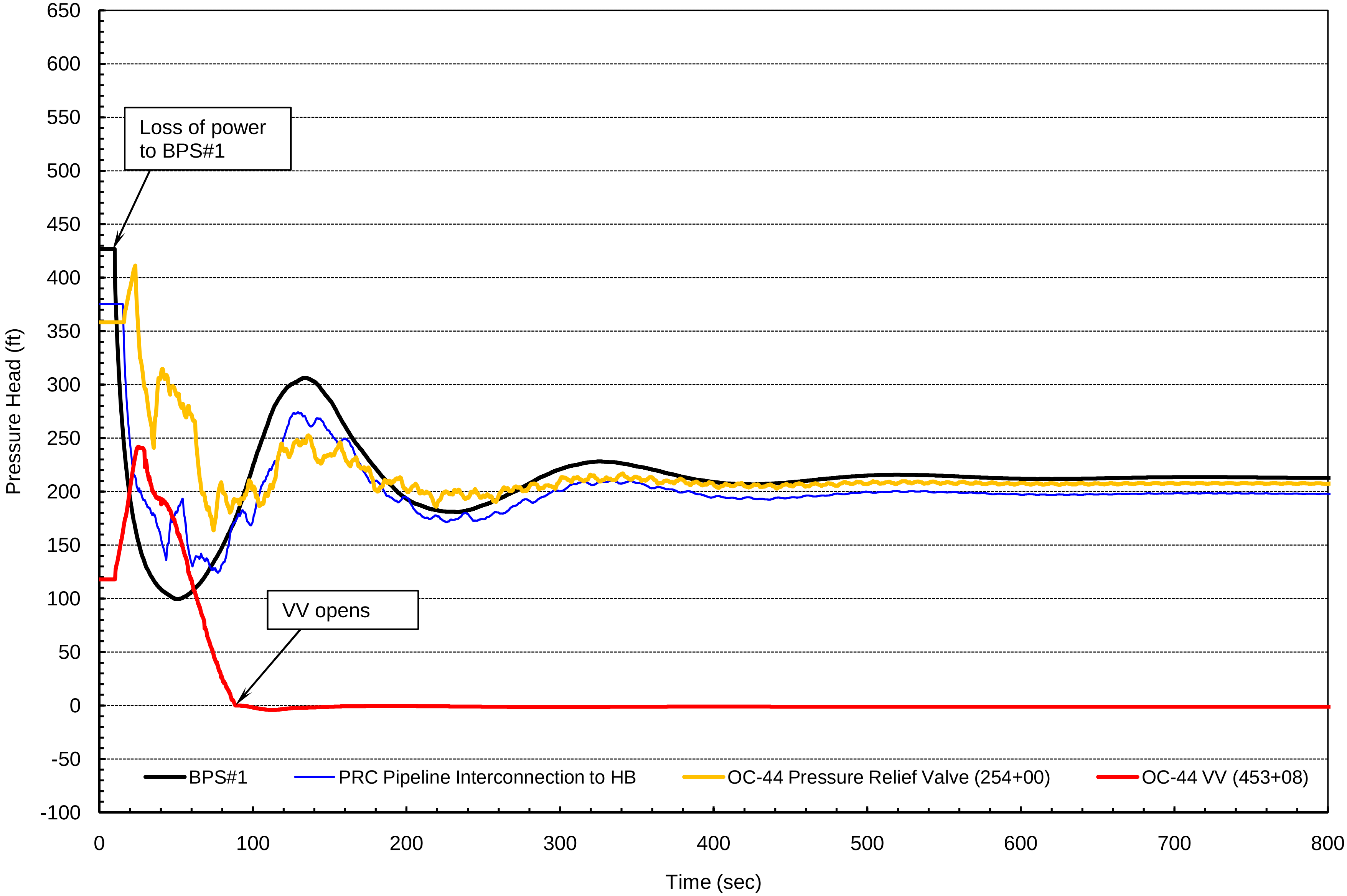

Figure 25: Pressure head records in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

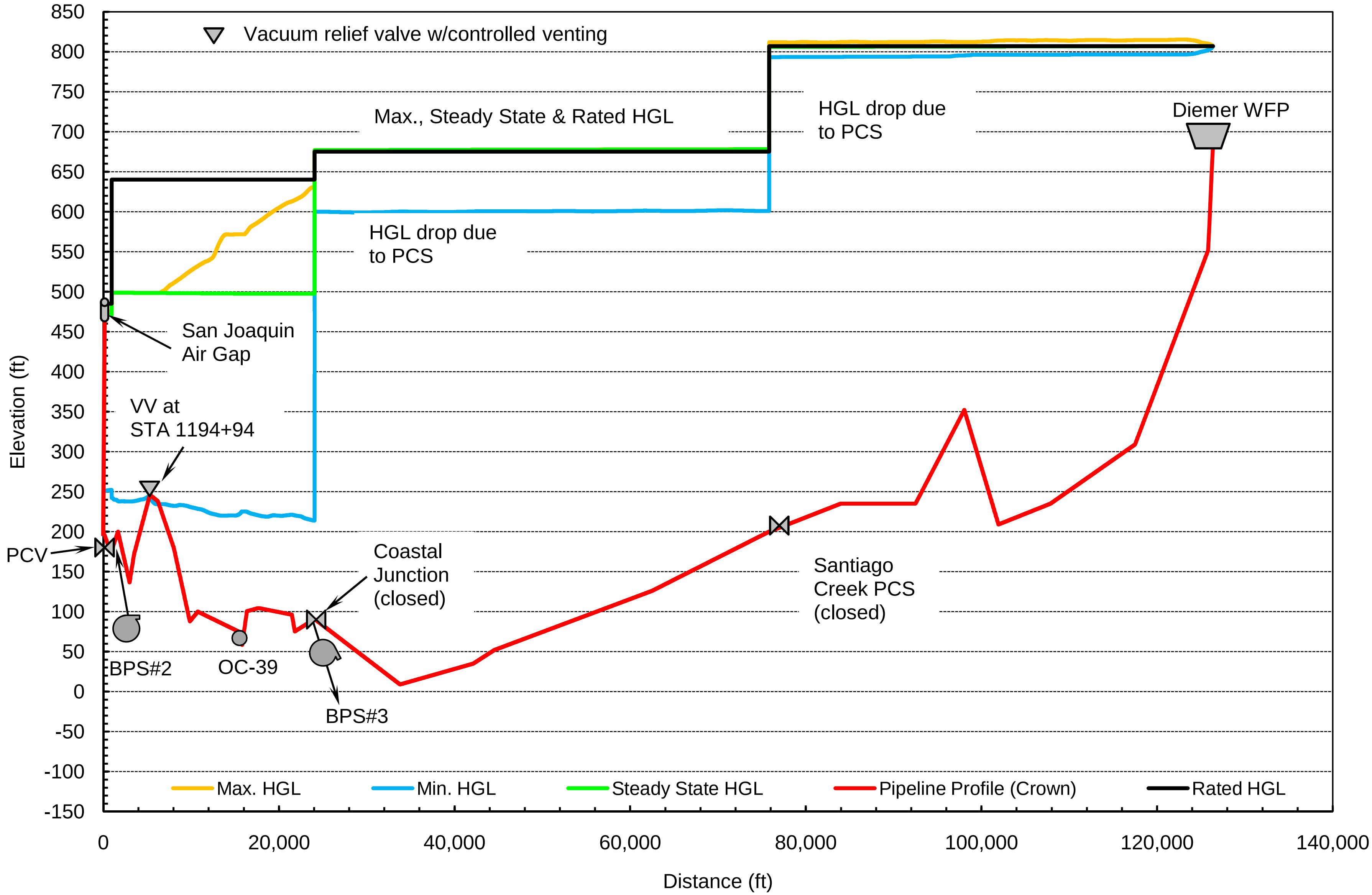

Figure 26: HGL elevations in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

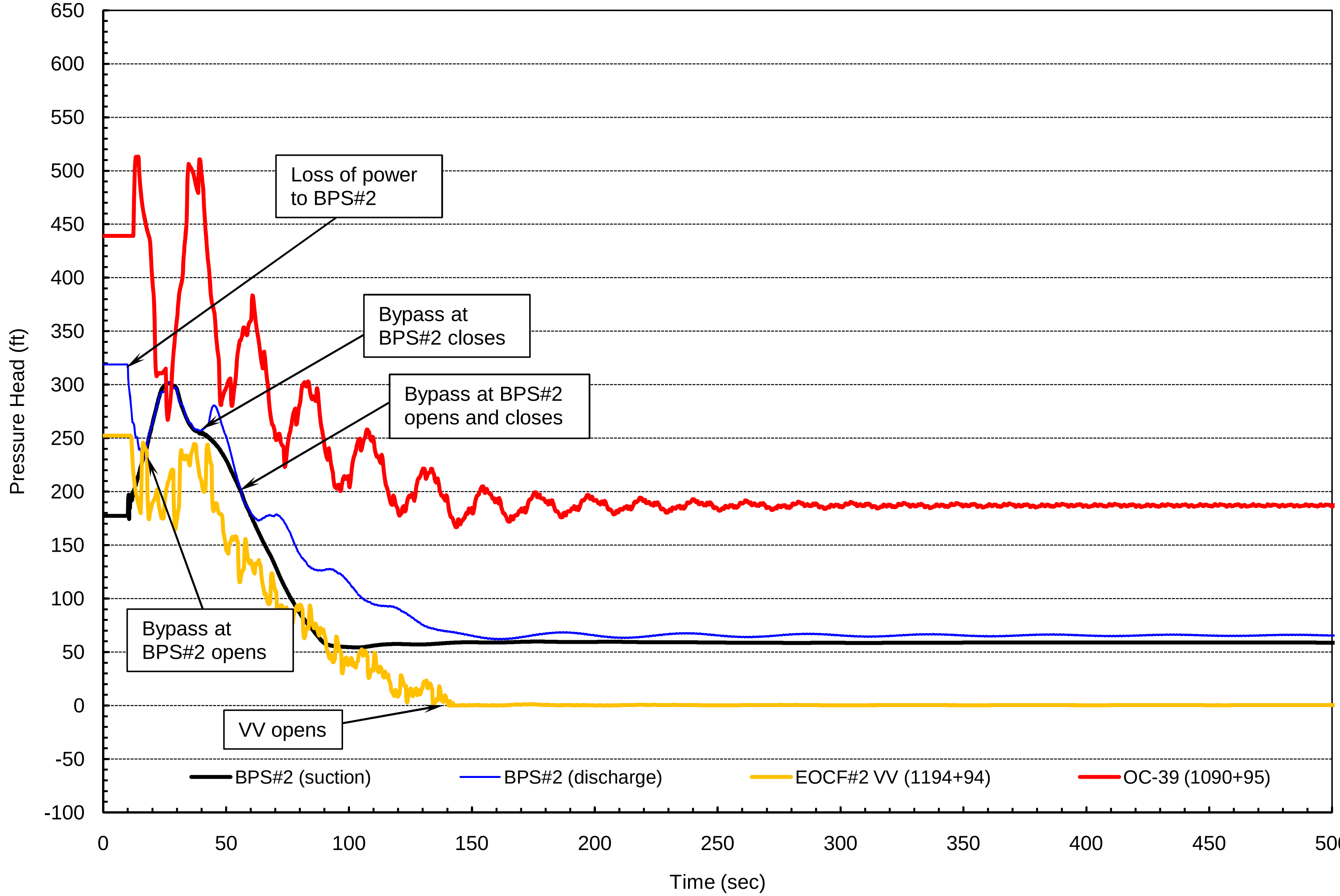

Figure 27: Pressure head records in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

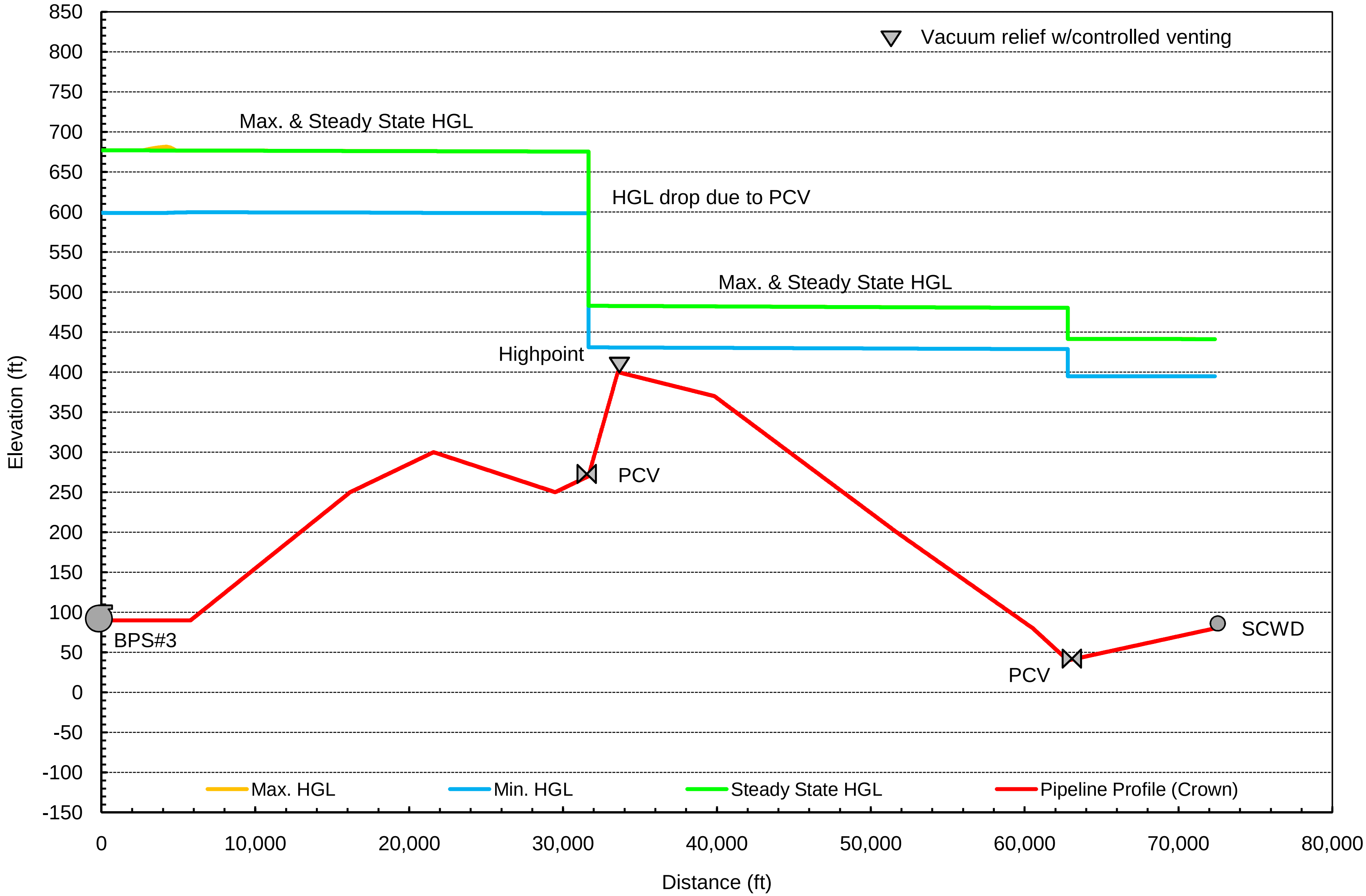

Figure 28: HGL elevations in Path C (Aufdenkamp TM) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

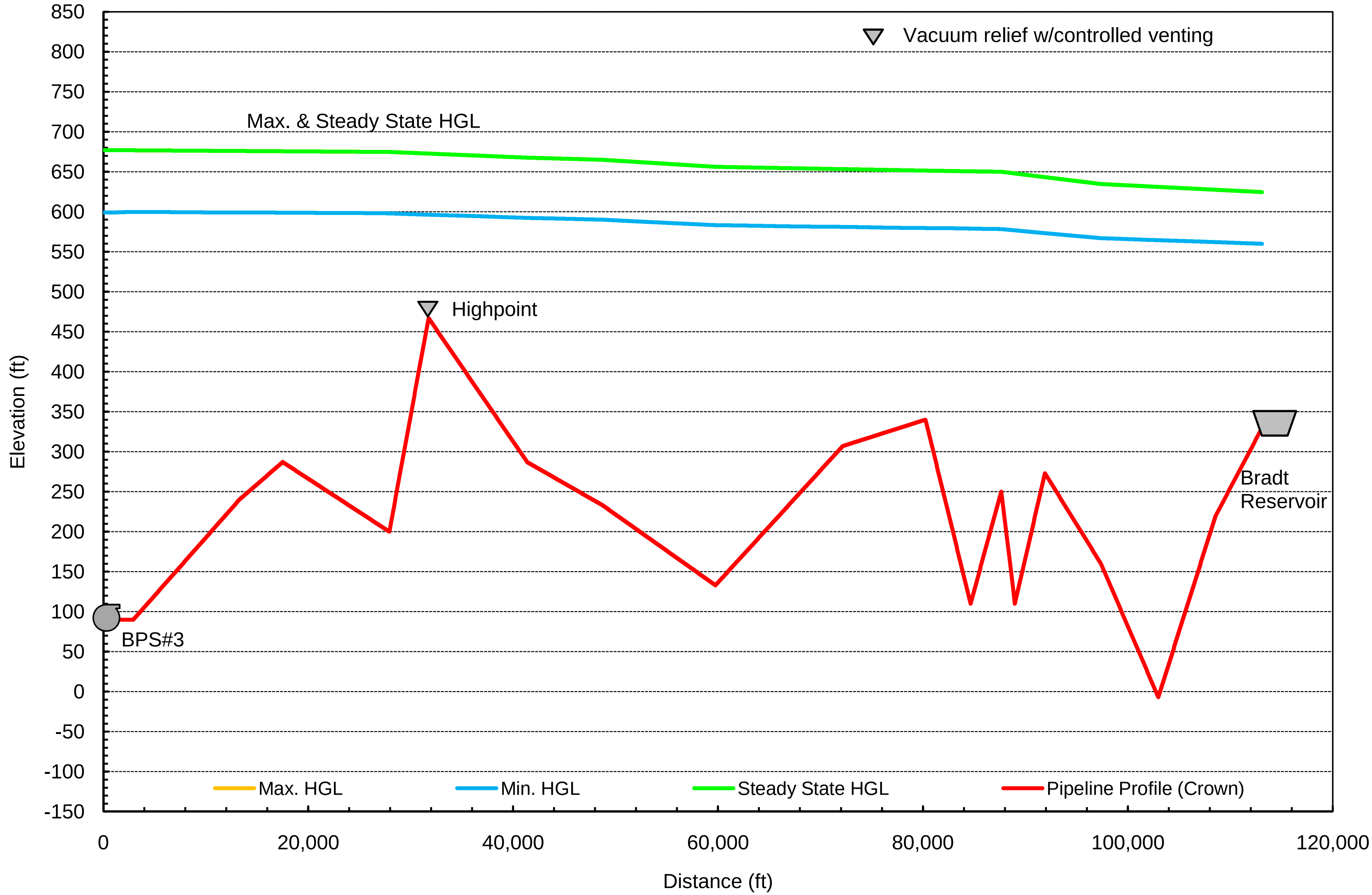

Figure 29: HGL elevations in Path D (Joint TM) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

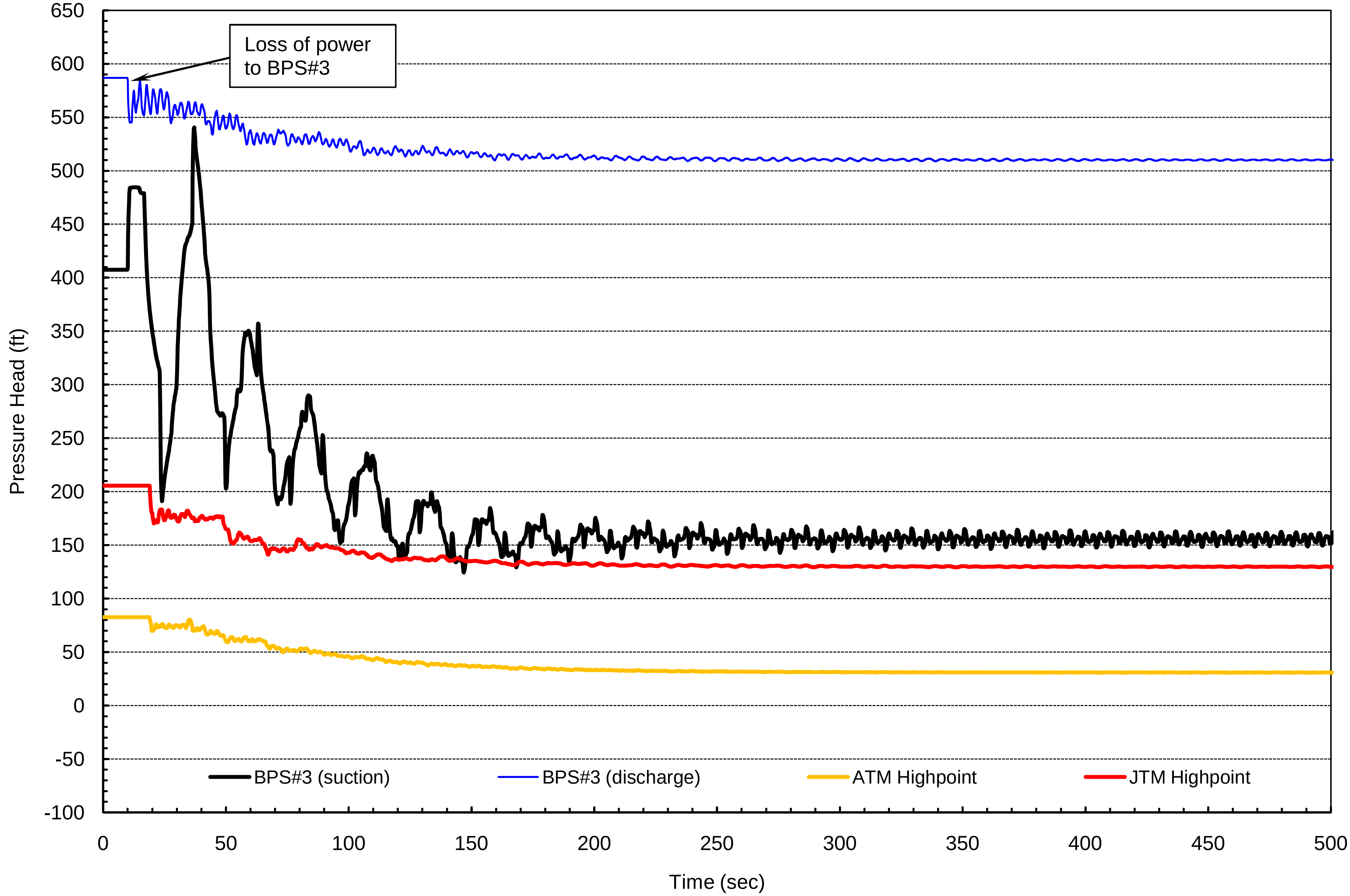

Figure 30: Pressure head records in Paths C and D (Aufdenkamp and Joint TMs) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

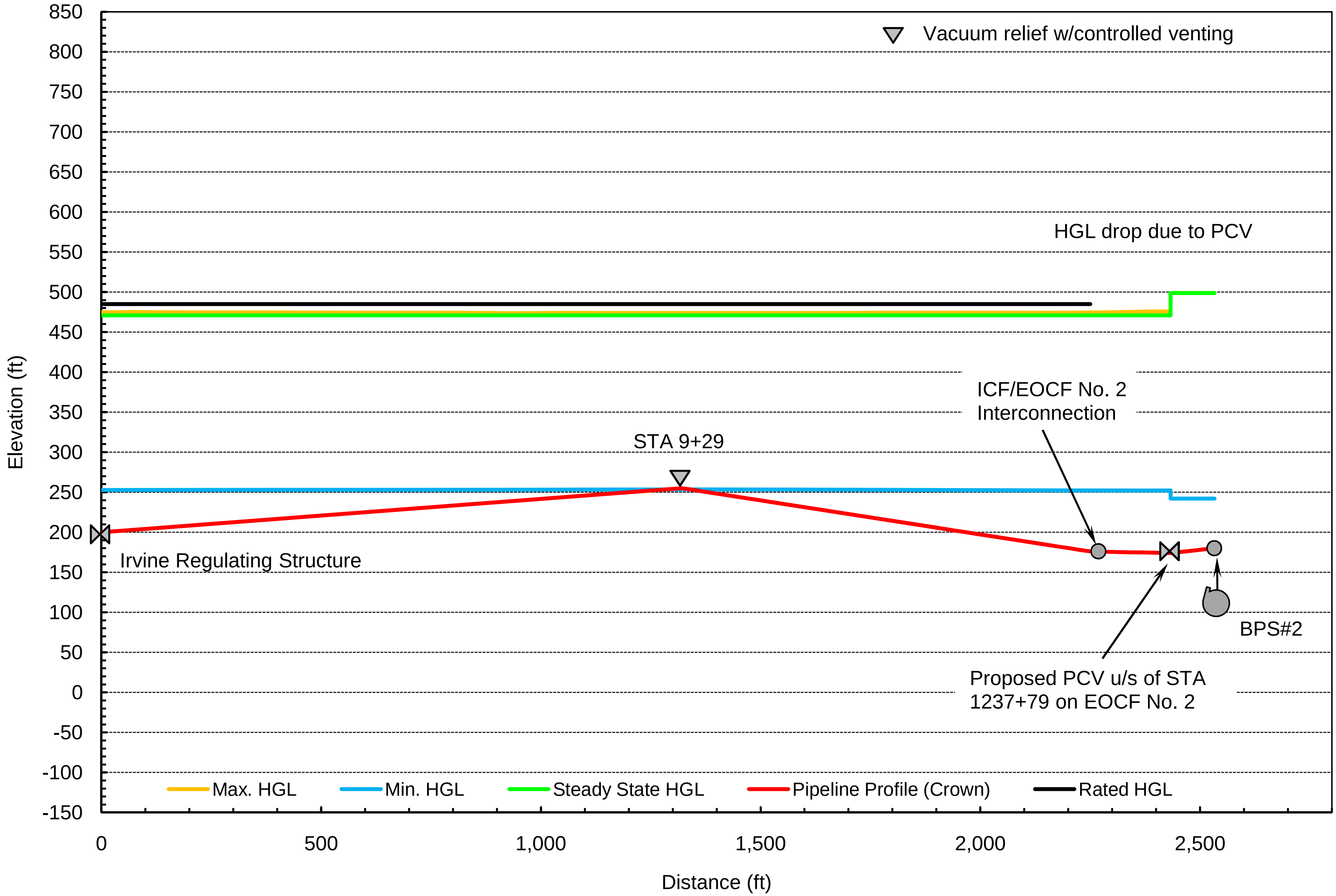

Figure 31: HGL elevations in Path E (Irvine Cross Feeder) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

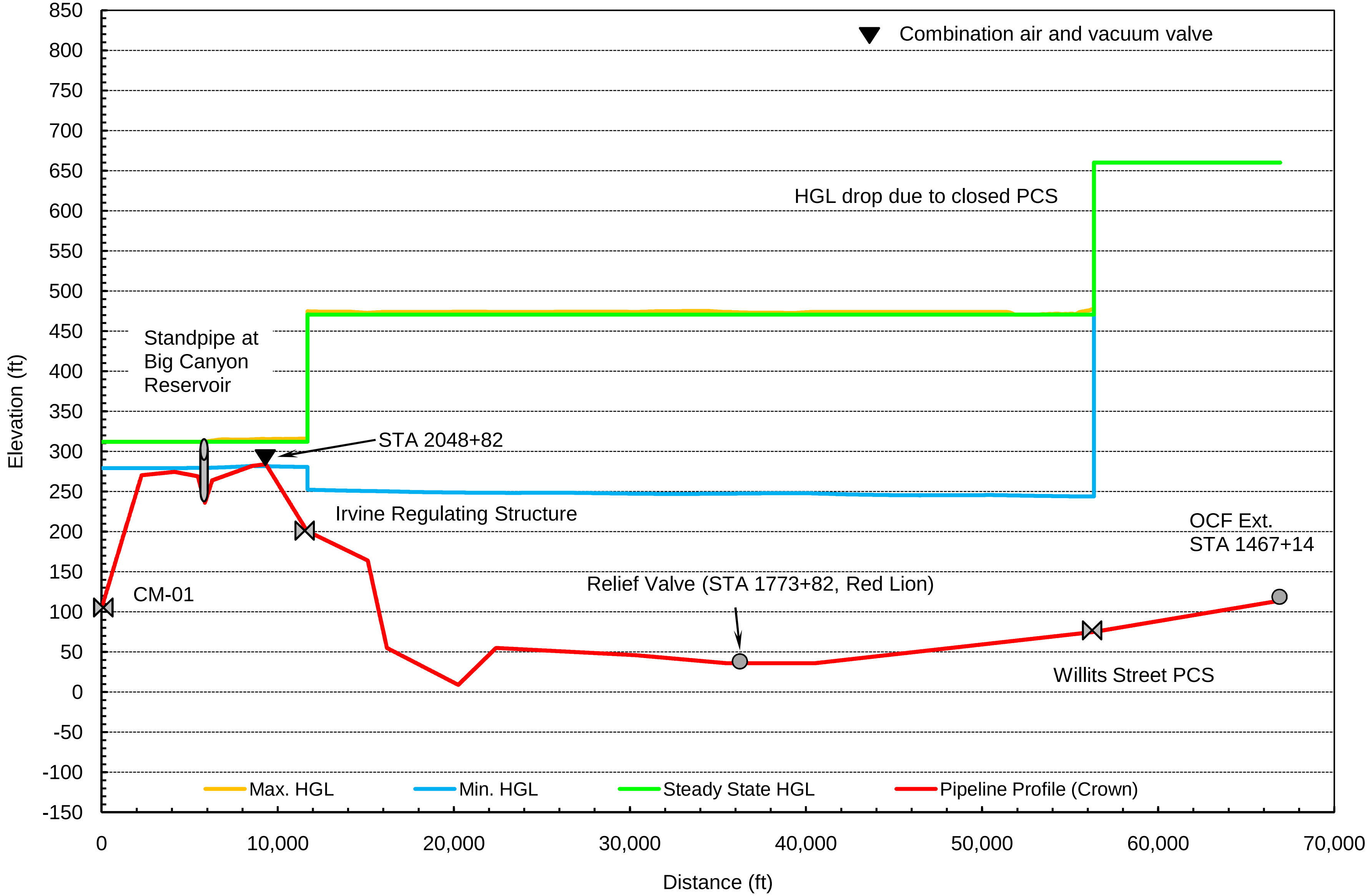

Figure 32: HGL elevations in Path F (OCF Ext.) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

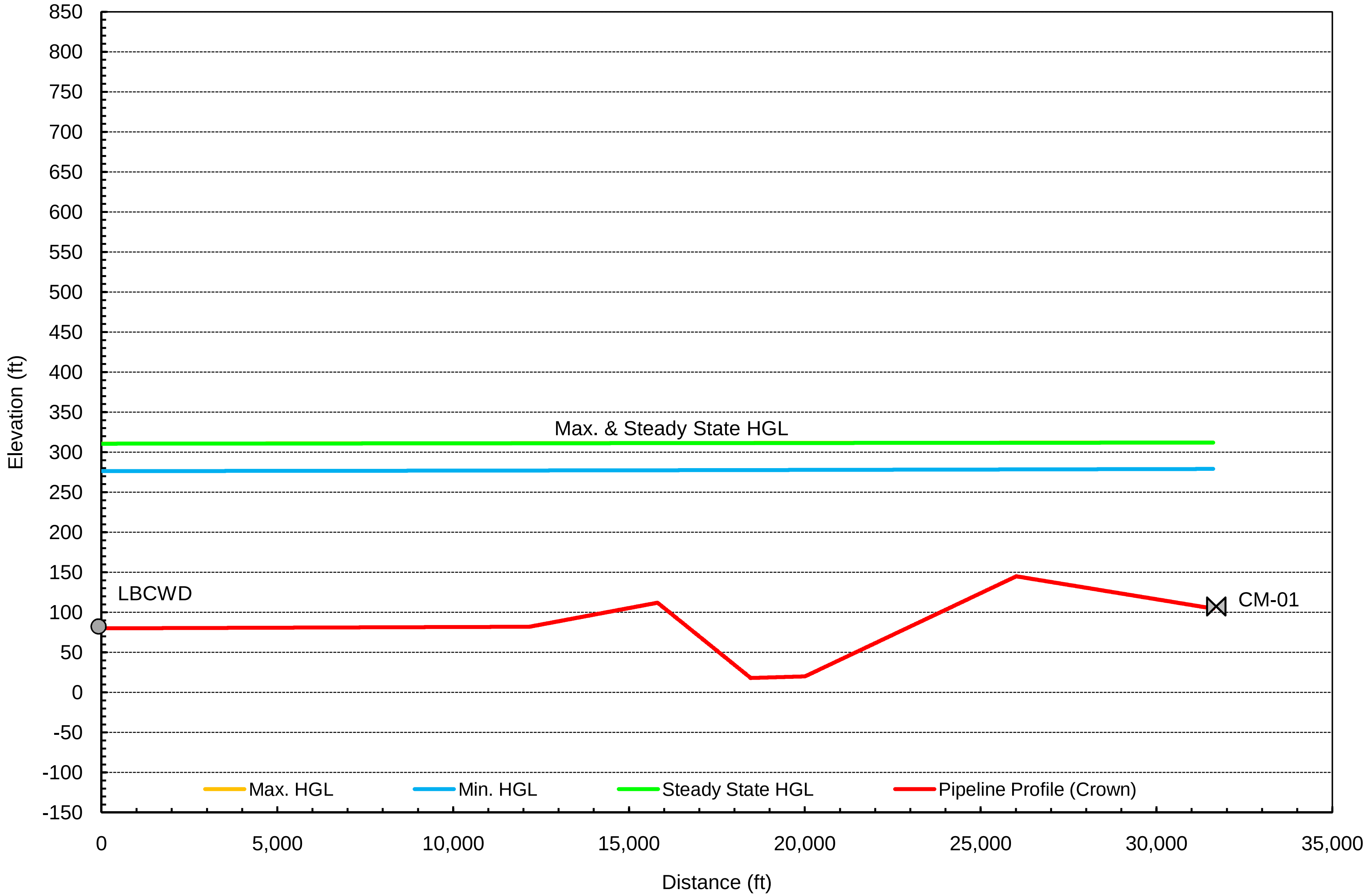

Figure 33: HGL elevations in Path G (Coastal Supply Line) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

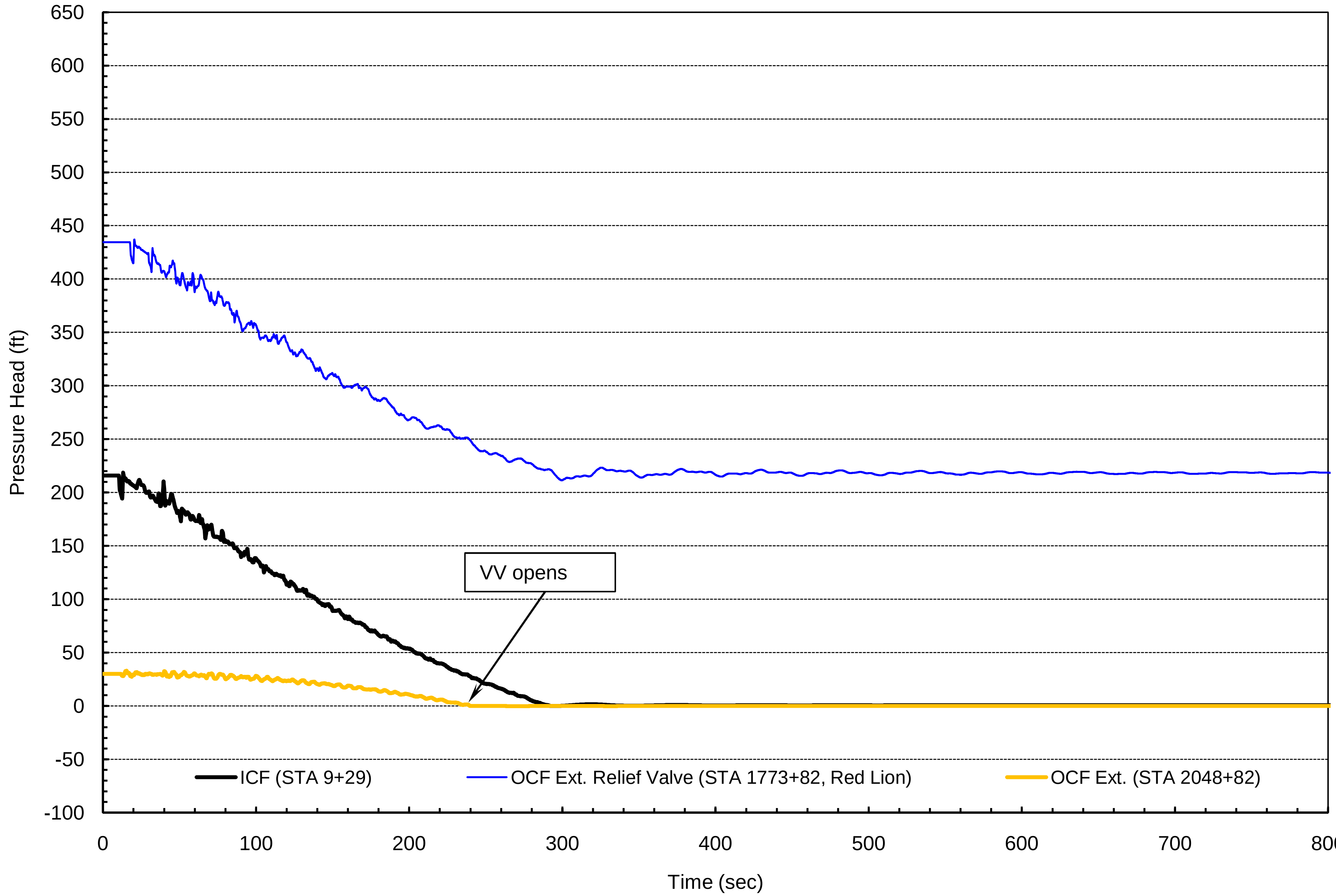

Figure 34: Pressure head records in Paths E and F (ICF and OCF Ext.) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

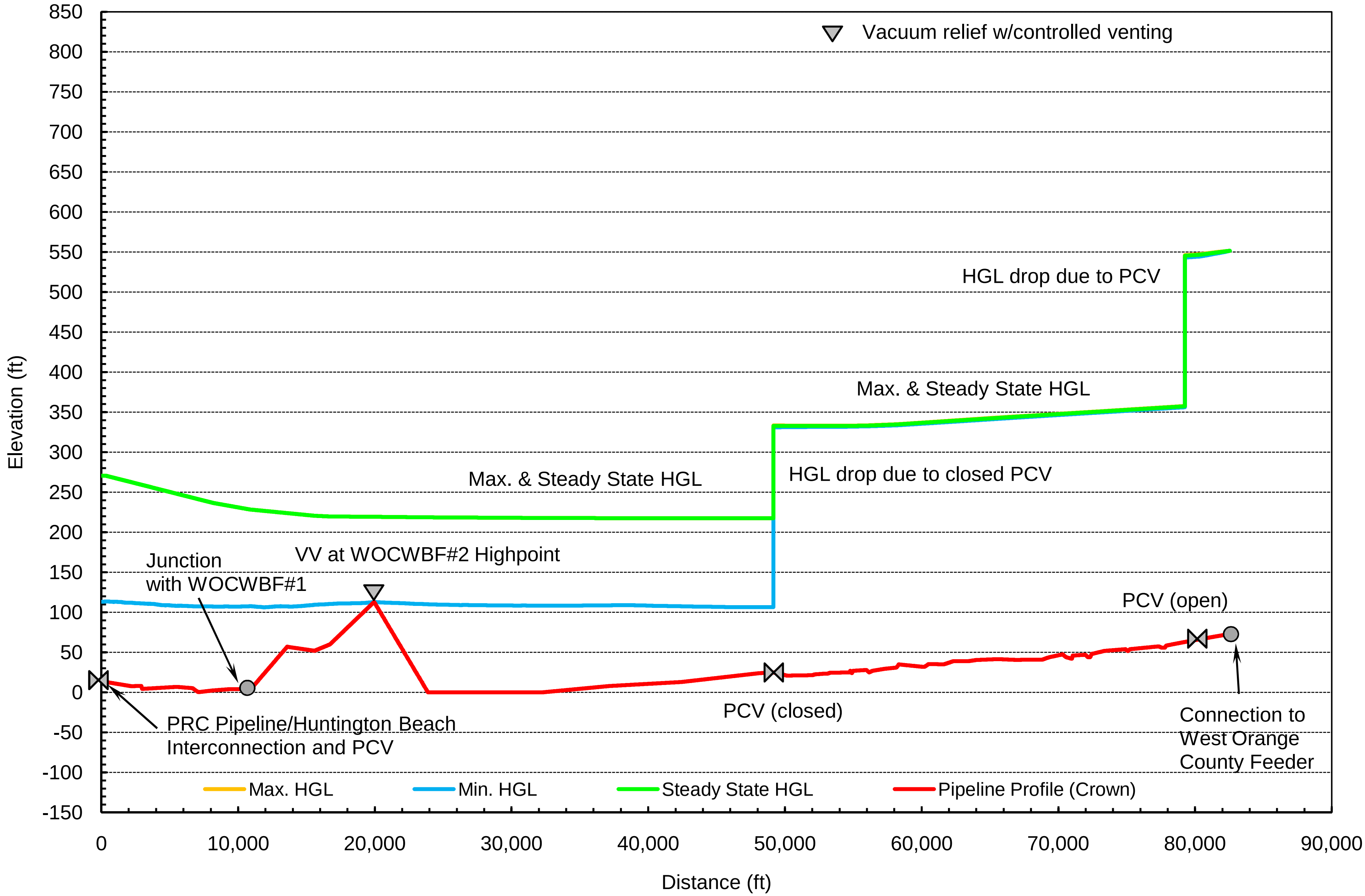

Figure 35: HGL elevations in Path H (WOCWBF#2) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

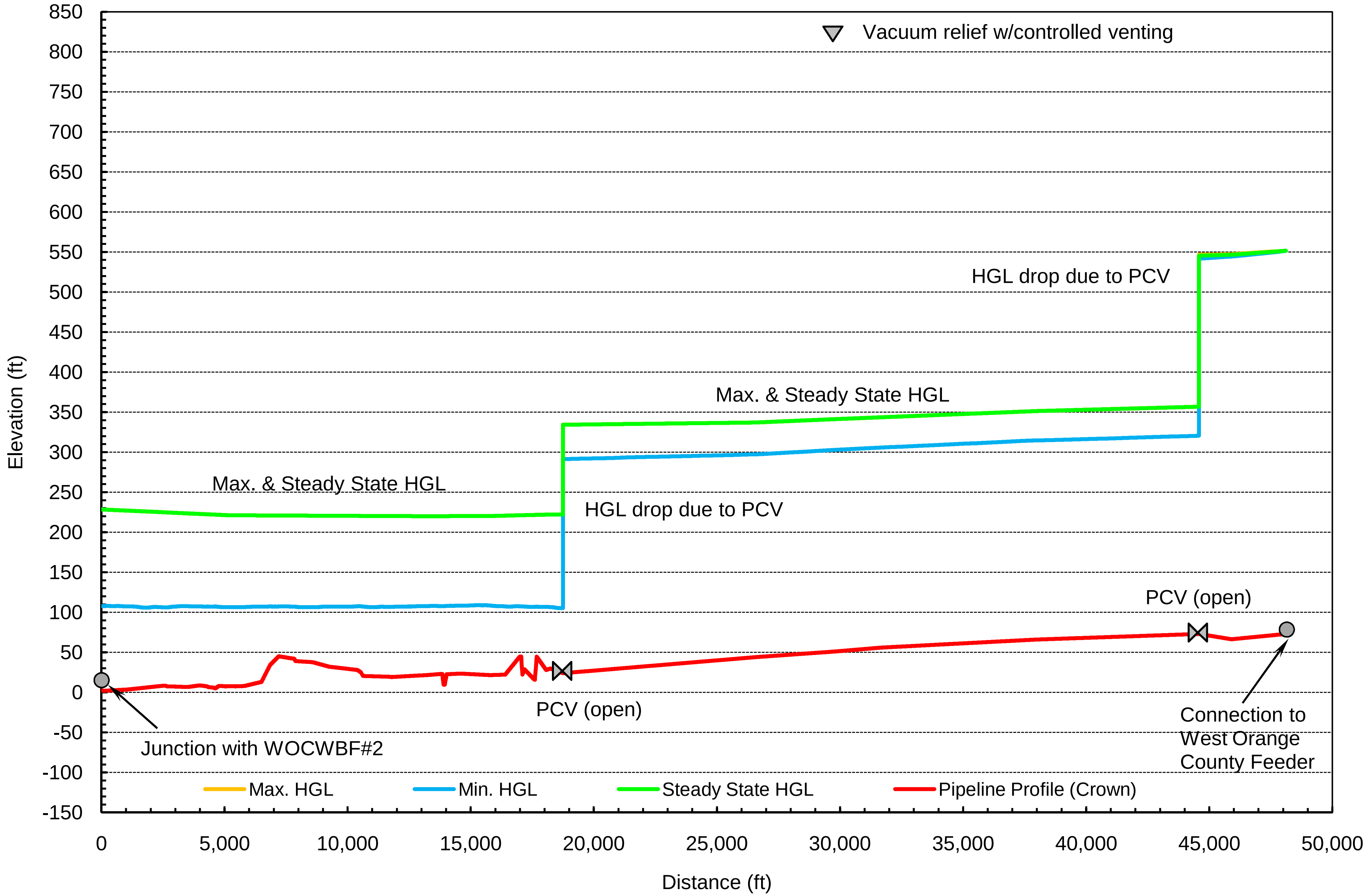

Figure 36: HGL elevations in Path I (WOCWBF#1) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

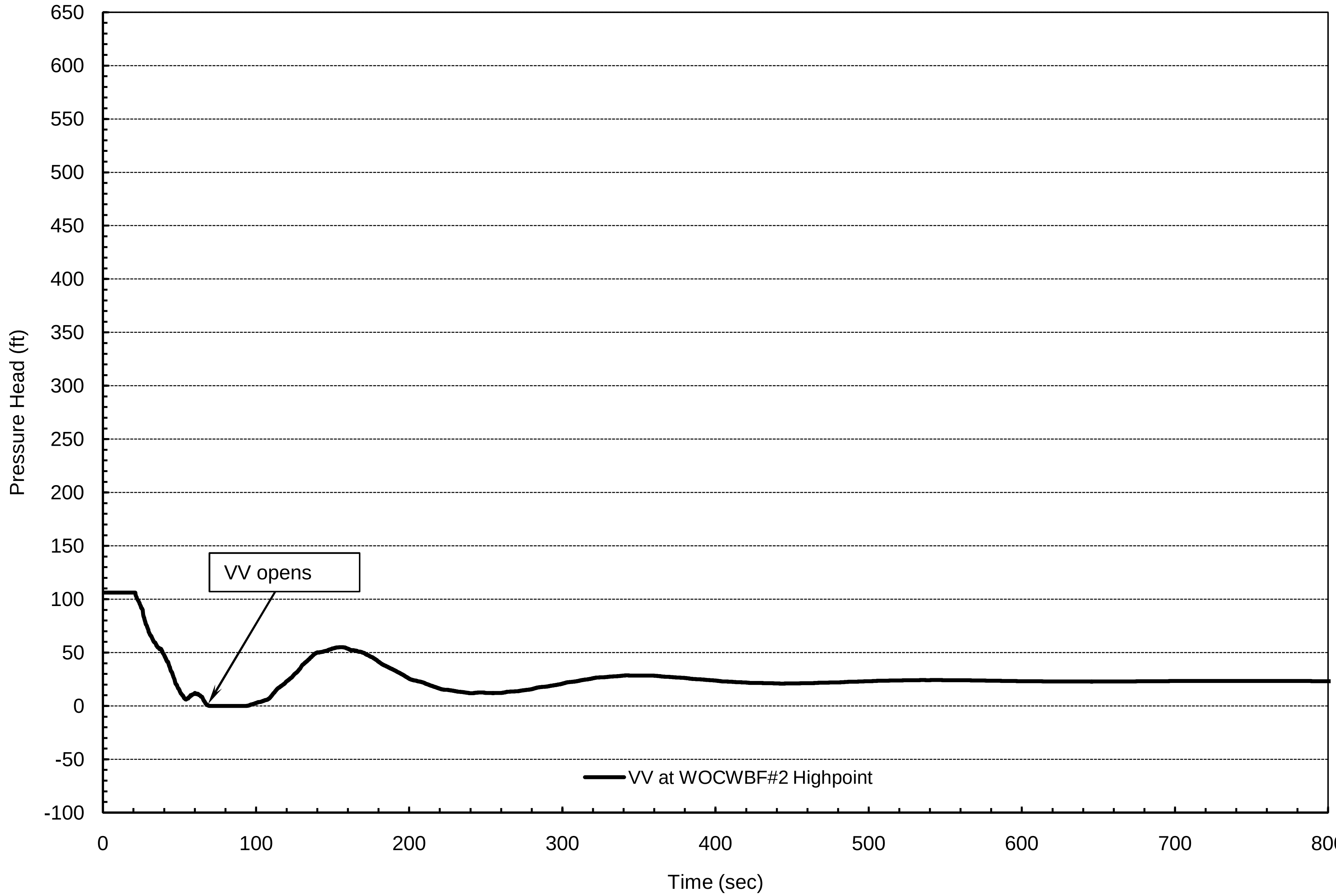

Figure 37: Pressure head records in Path H (WOCWBF#2) following loss of power to booster pump stations under Operating Scenario 2 with surge protection

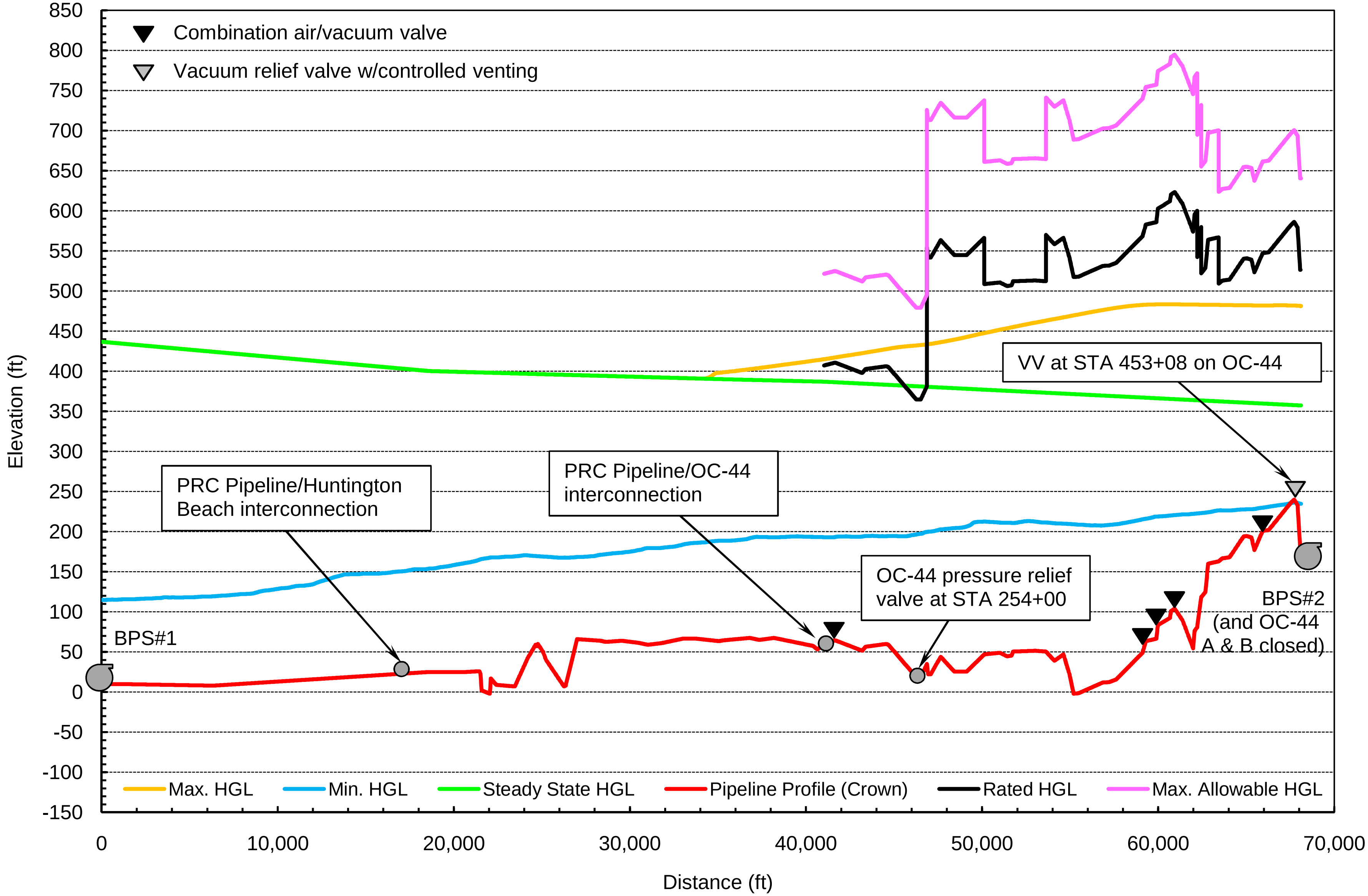

Figure 38: HGL elevations in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

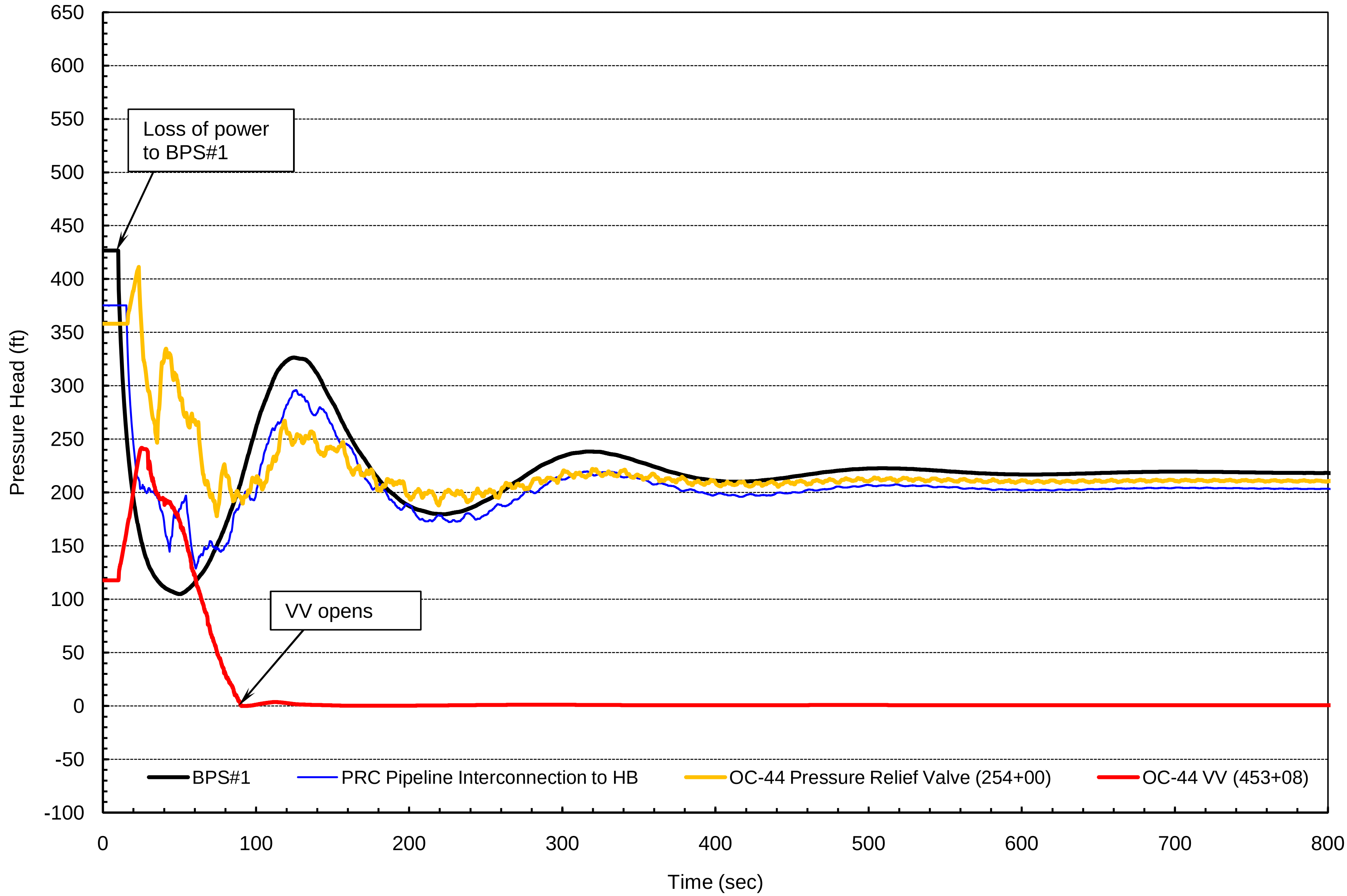

Figure 39: Pressure head records in Path A (PRC Pipeline and OC-44 TM) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

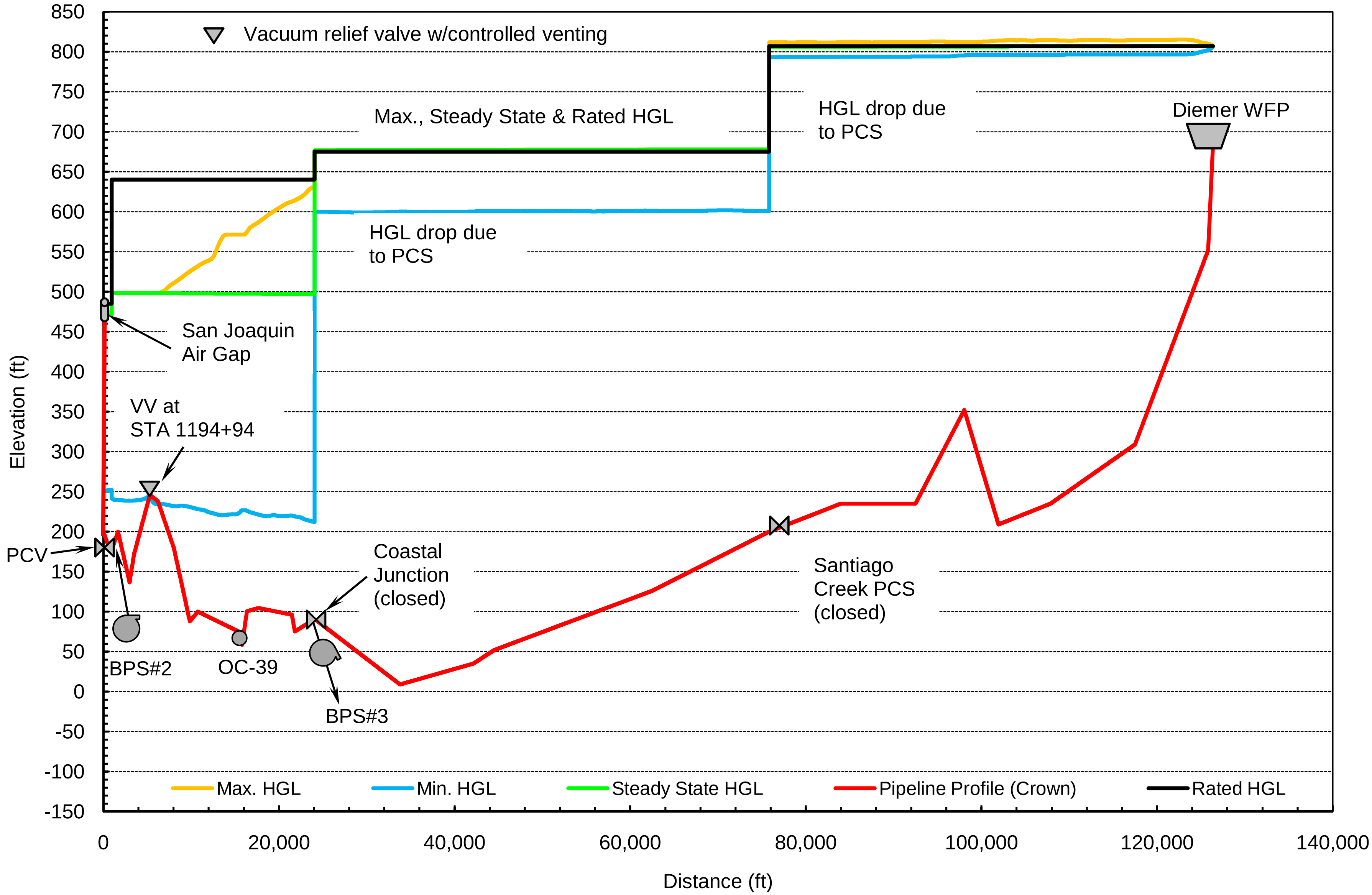

Figure 40: HGL elevations in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

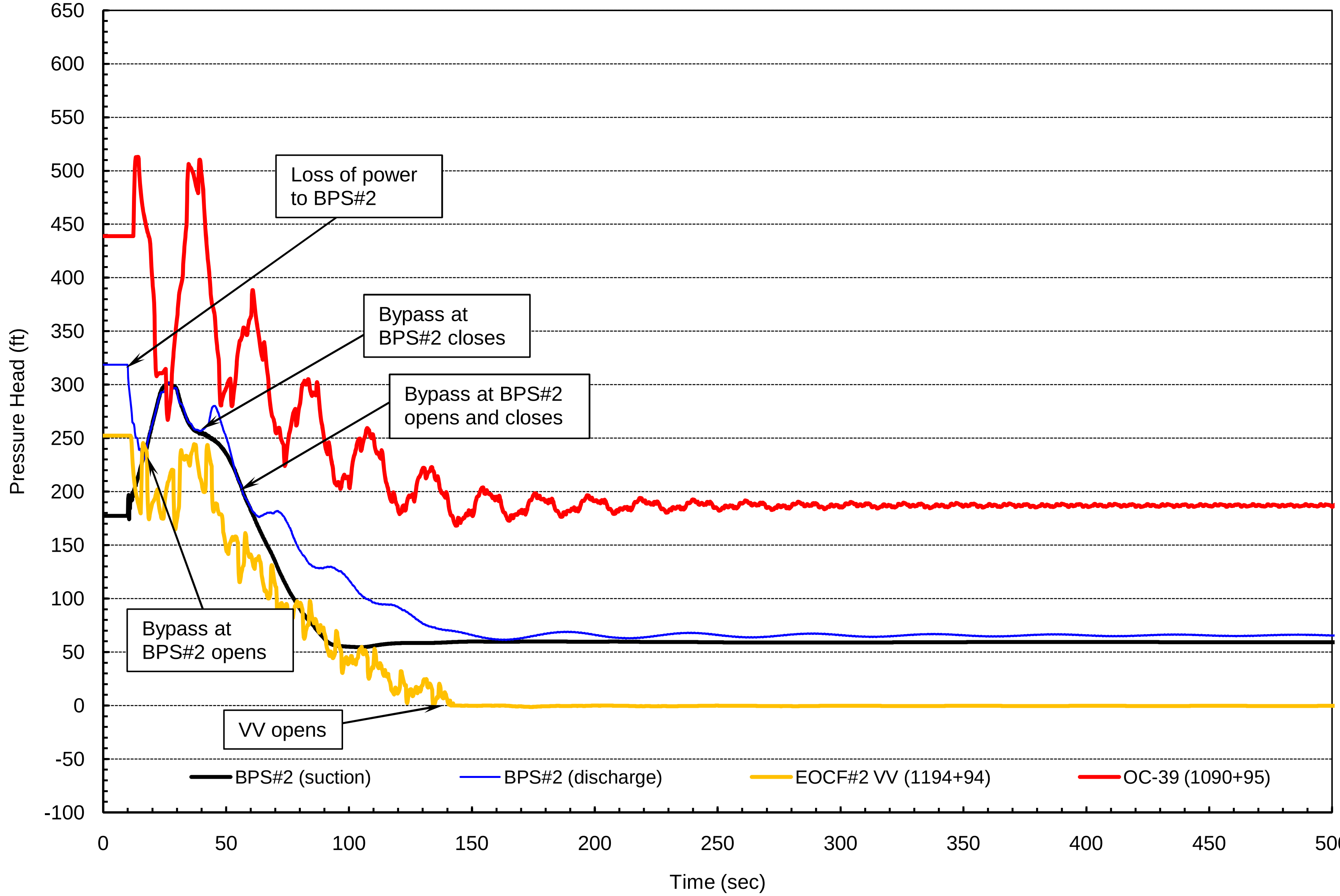

Figure 41: Pressure head records in Path B (EOCF#2) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

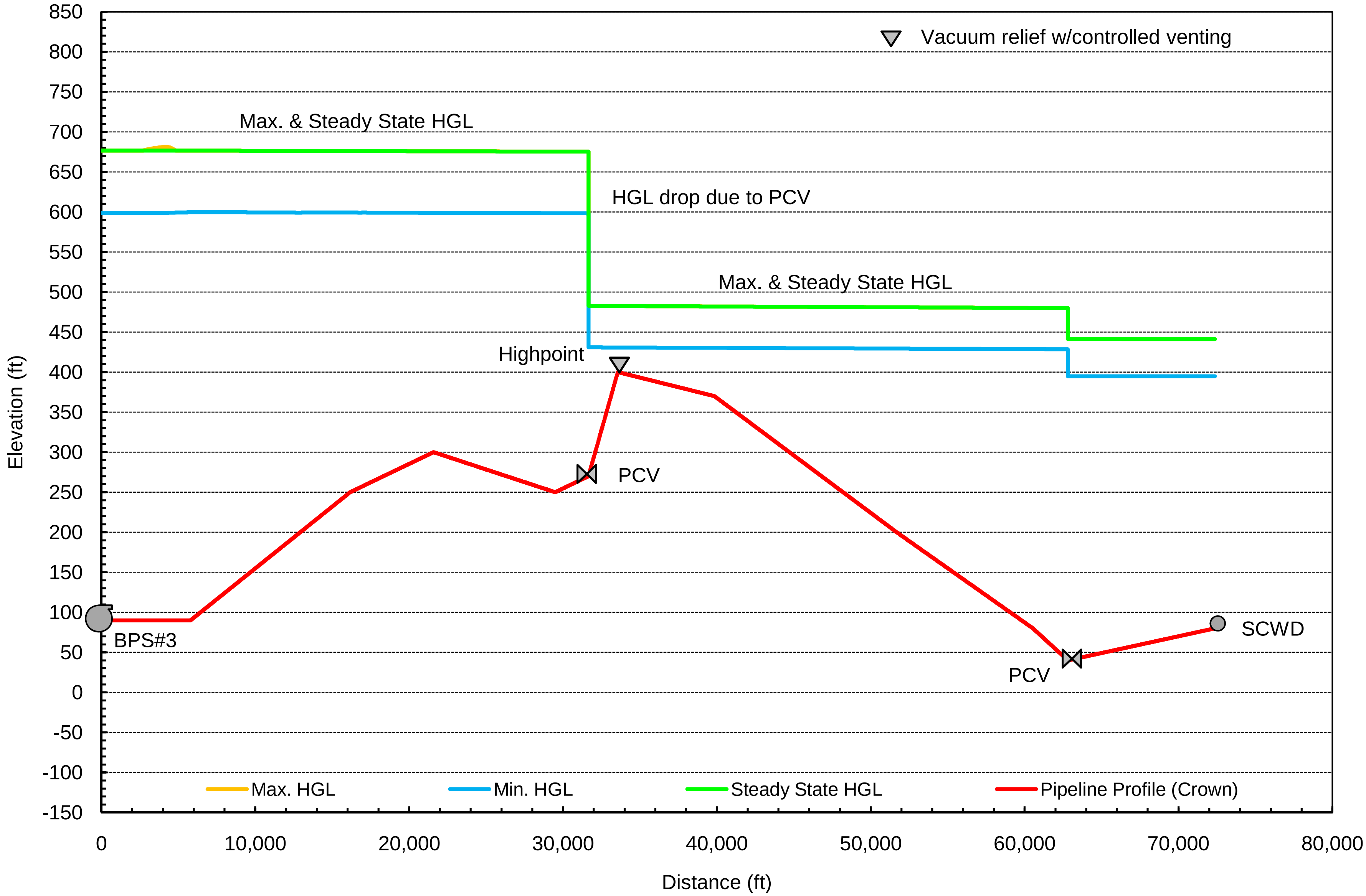

Figure 42: HGL elevations in Path C (Aufdenkamp TM) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

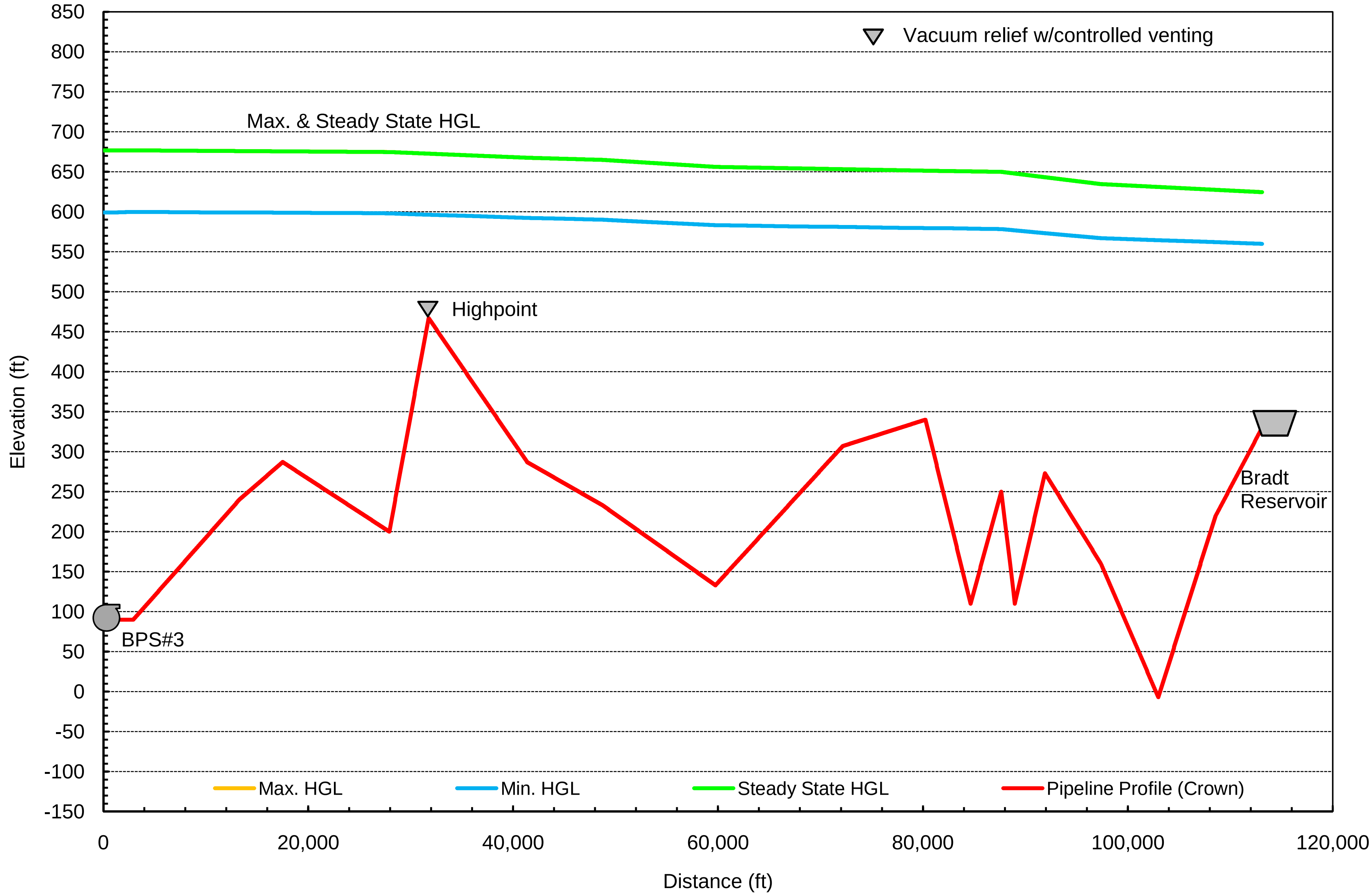

Figure 43: HGL elevations in Path D (Joint TM) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

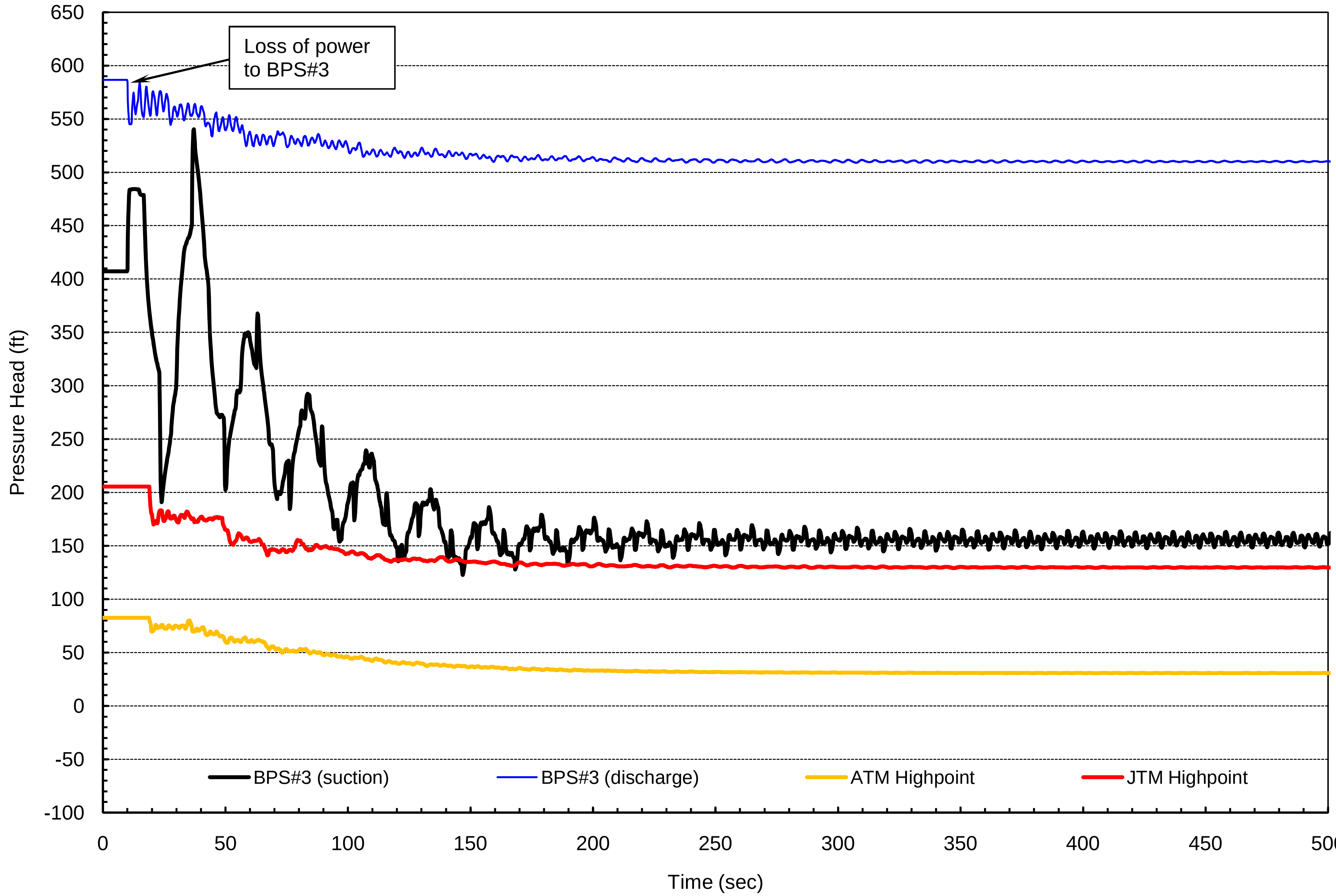

Figure 44: Pressure head records in Paths C and D (Aufdenkamp and Joint TMs) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

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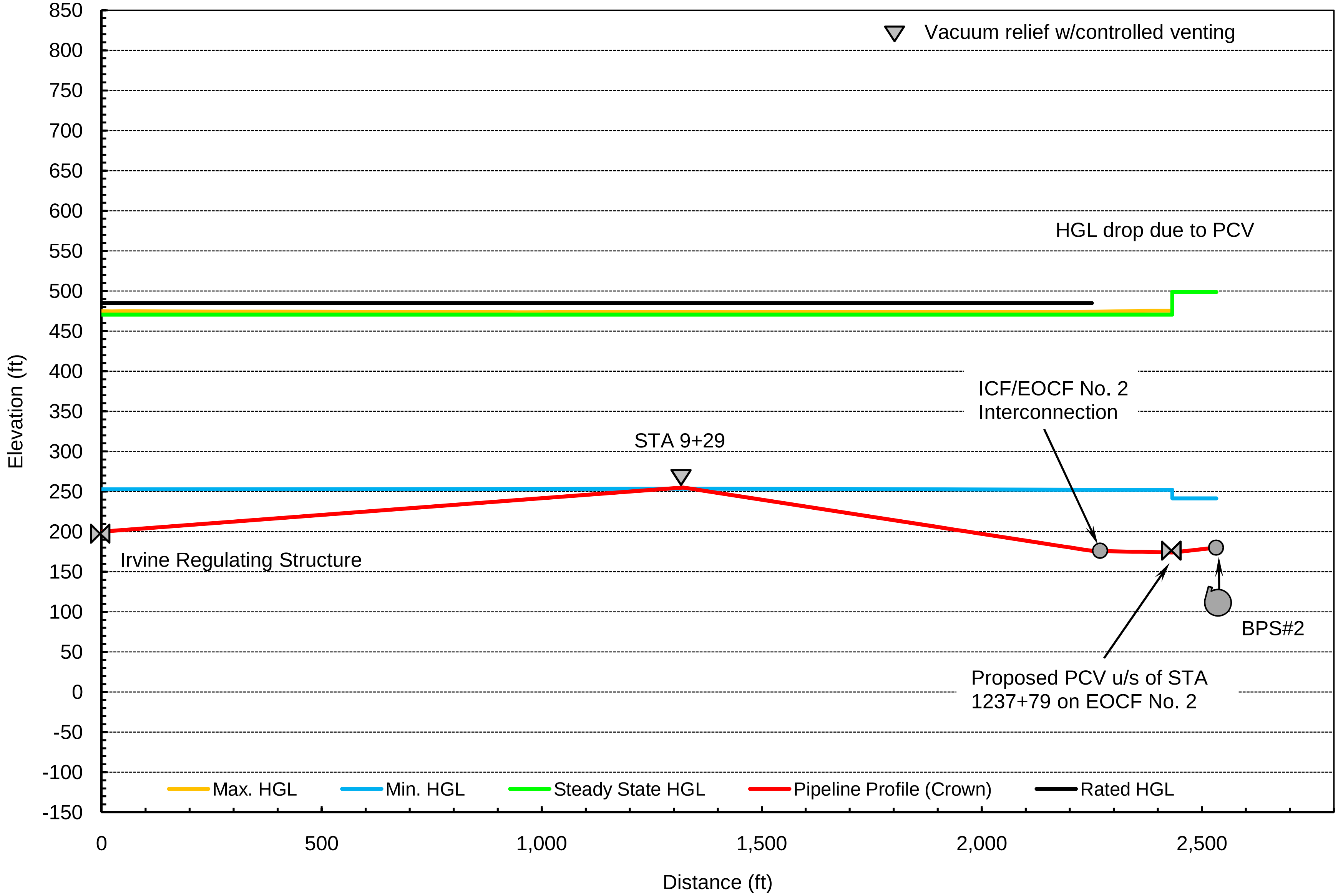

Figure 45: HGL elevations in Path E (Irvine Cross Feeder) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

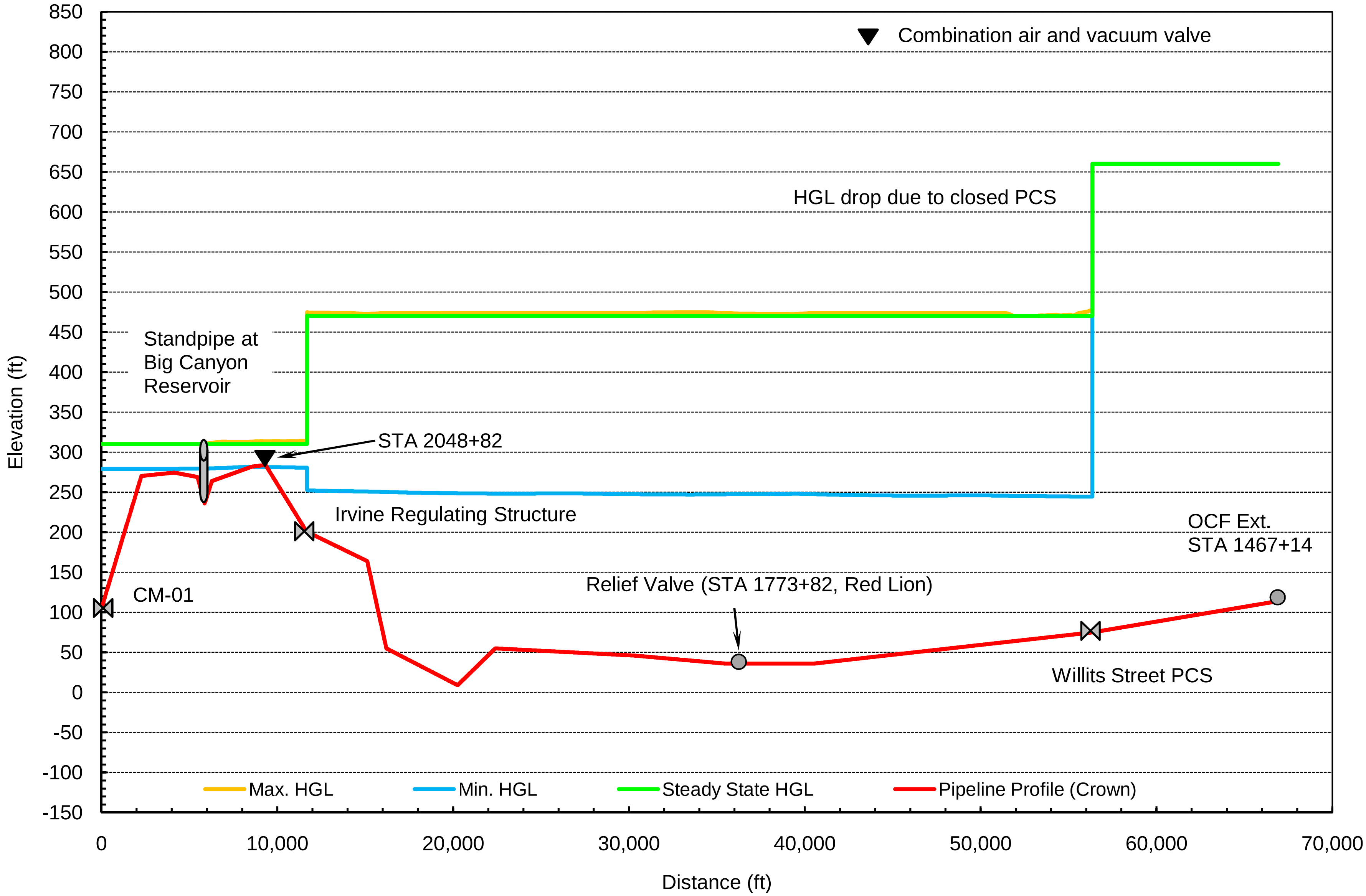

Figure 46: HGL elevations in Path F (OCF Ext.) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

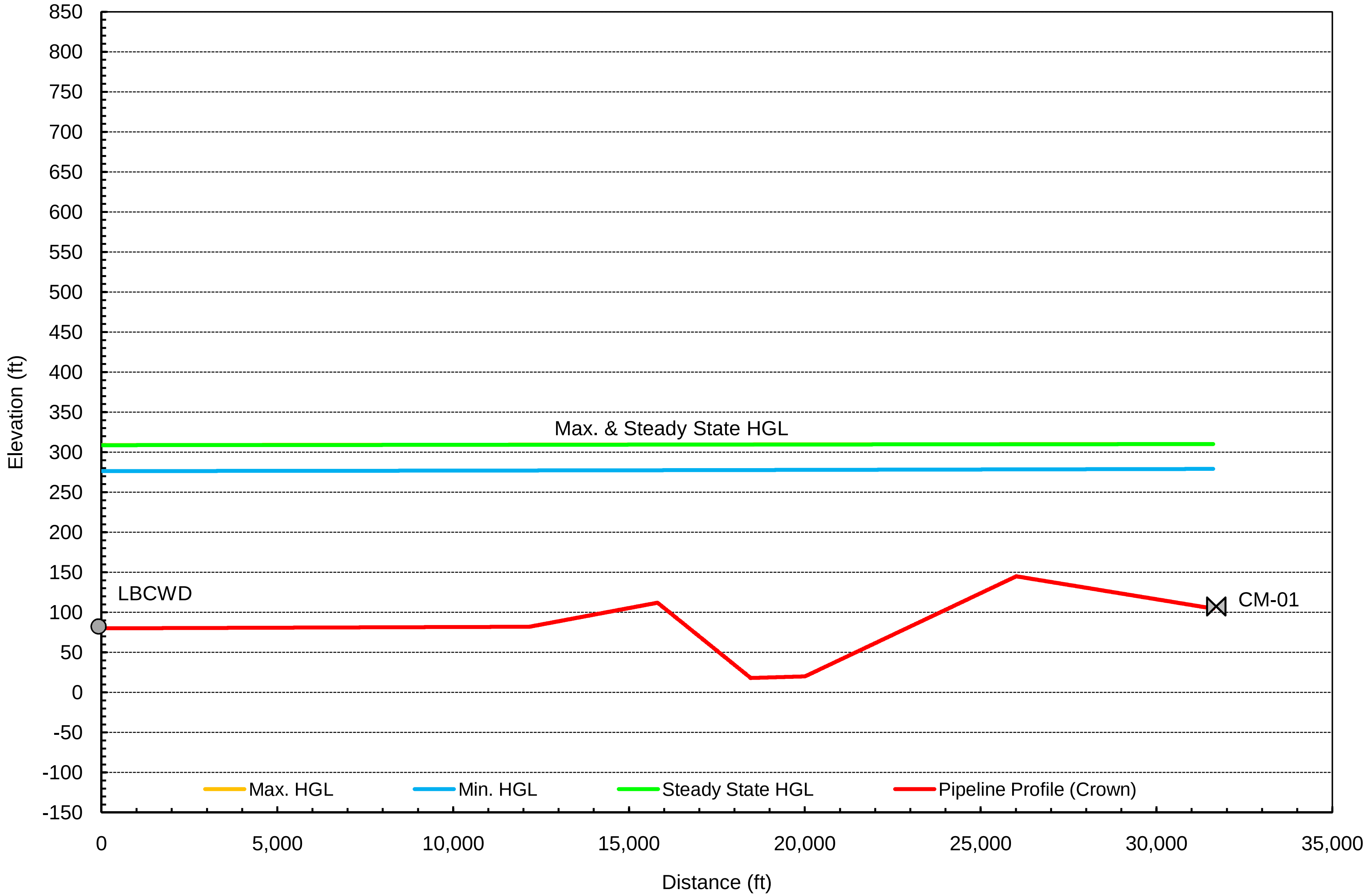

Figure 47: HGL elevations in Path G (Coastal Supply Line) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

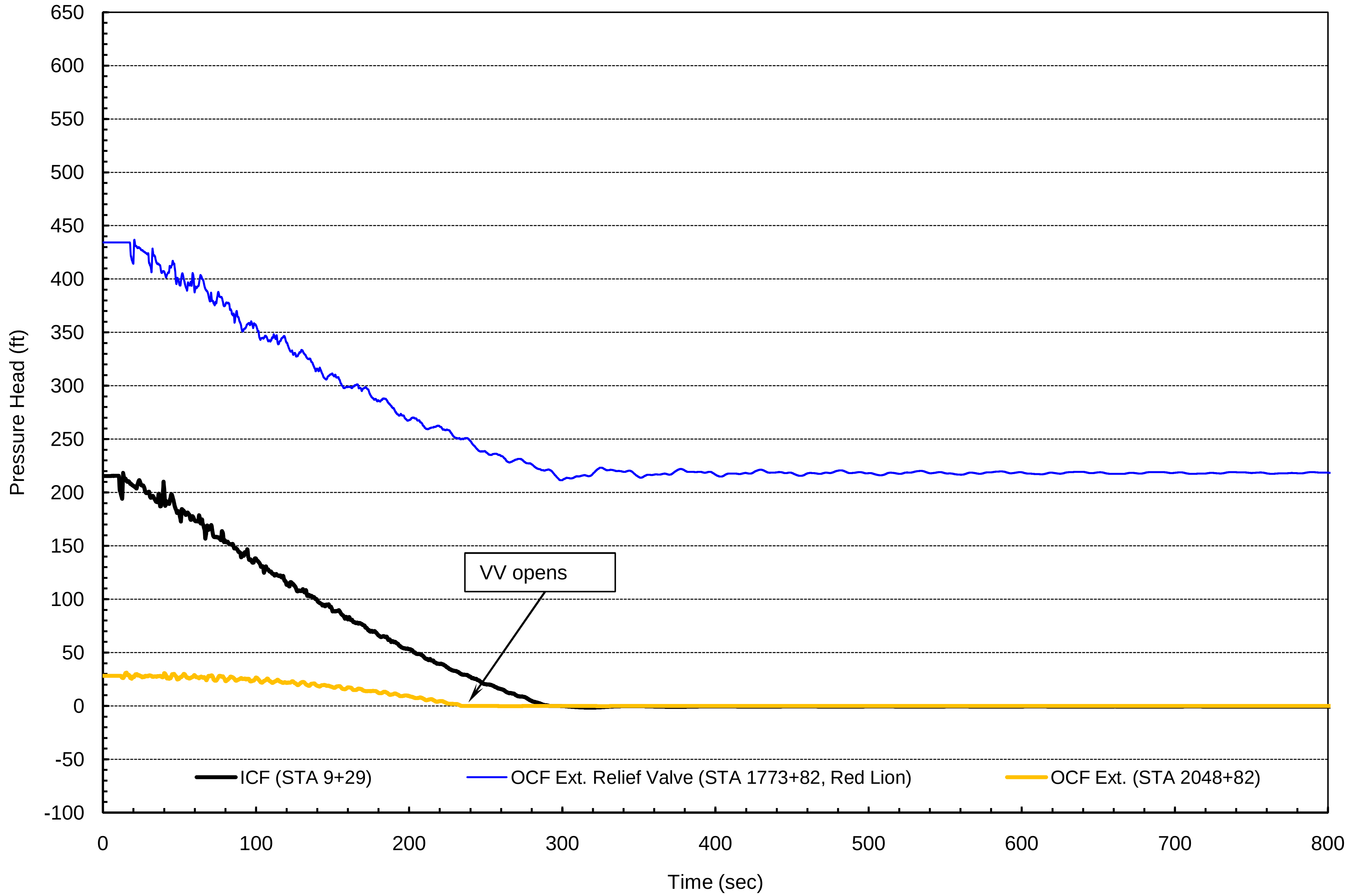

Figure 48: Pressure head records in Paths E and F (ICF and OCF Ext.) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

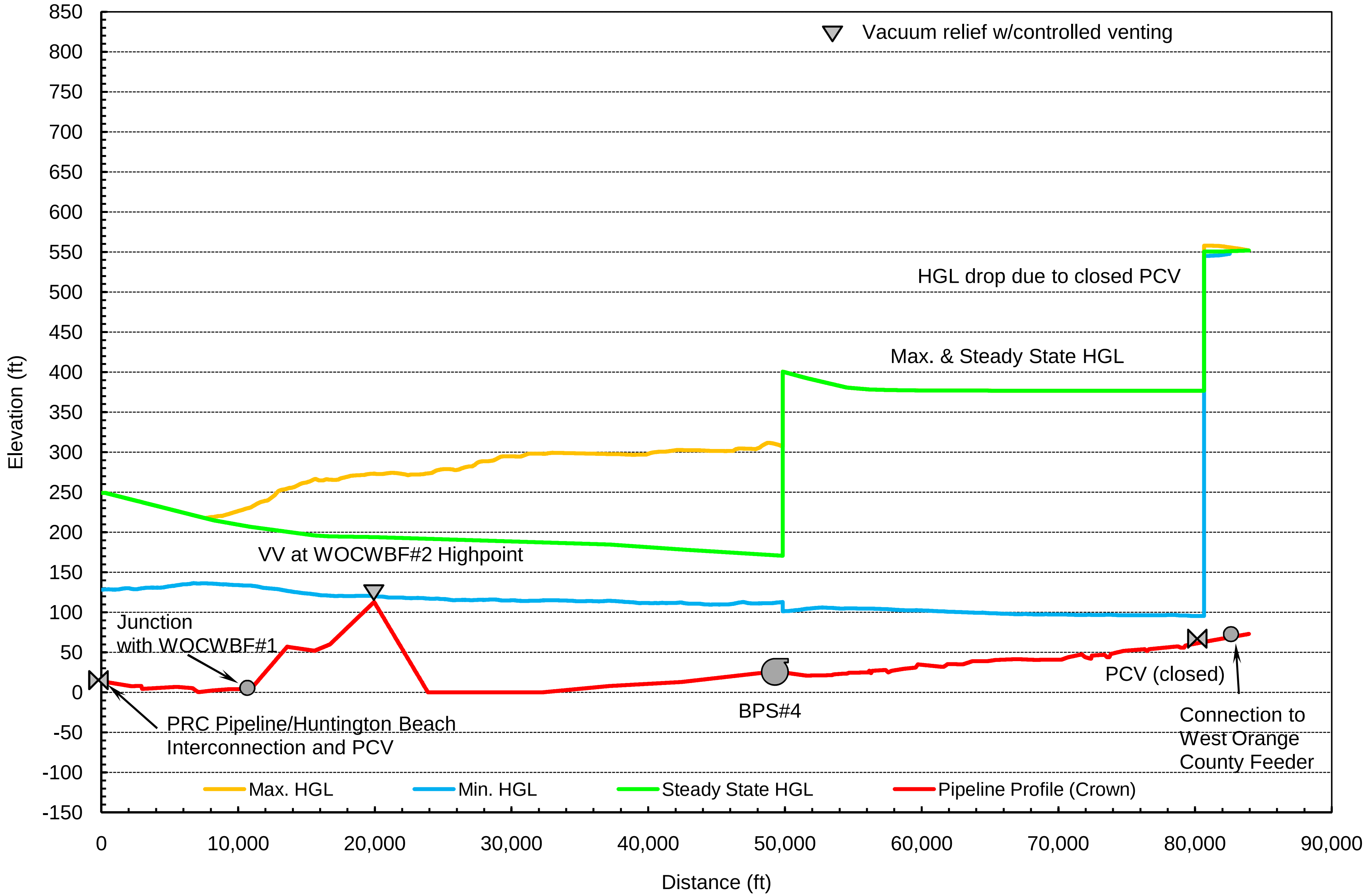

Figure 49: HGL elevations in Path H (WOCWBF#2) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

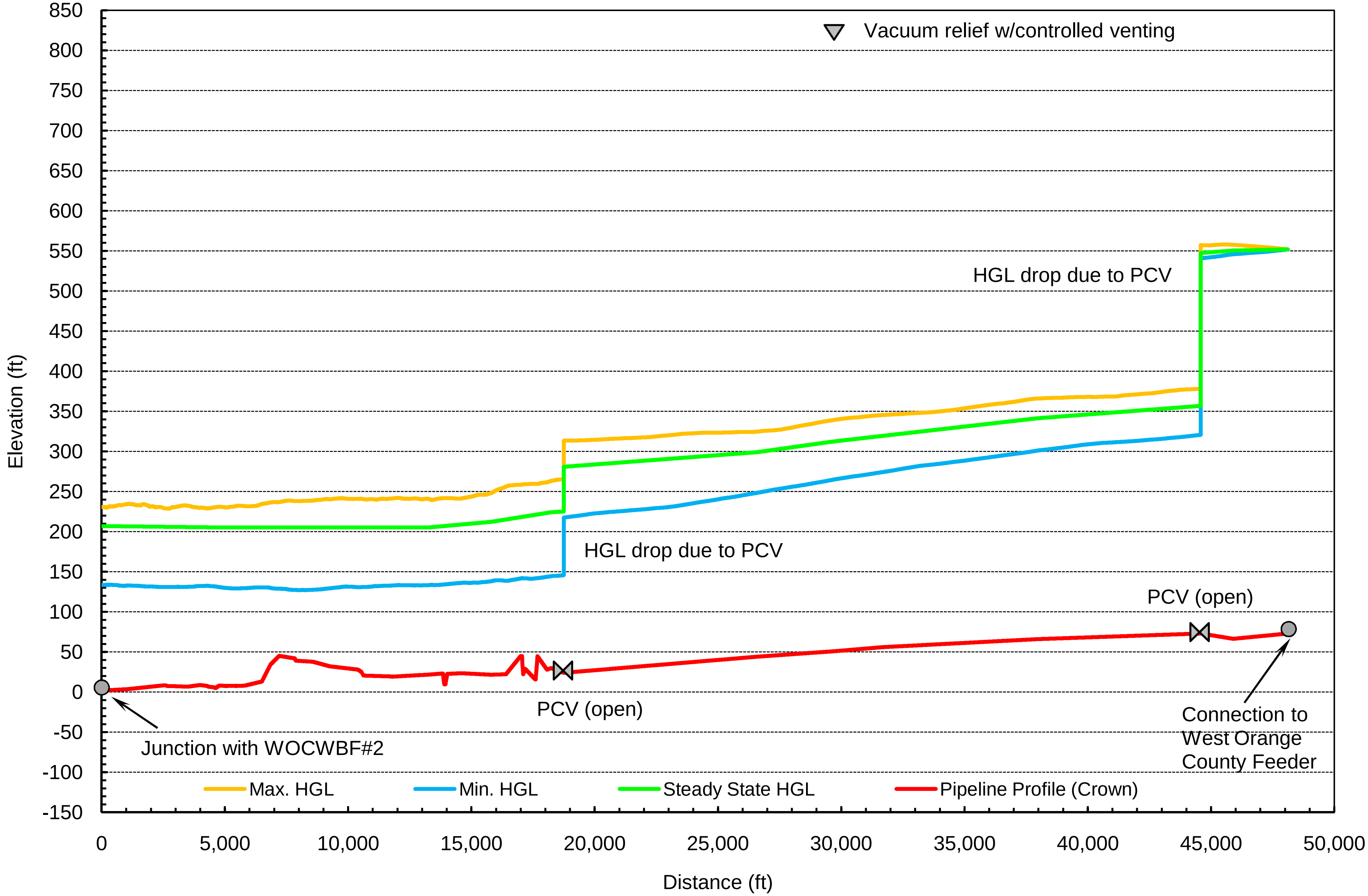

Figure 50: HGL elevations in Path I (WOCWBF#1) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

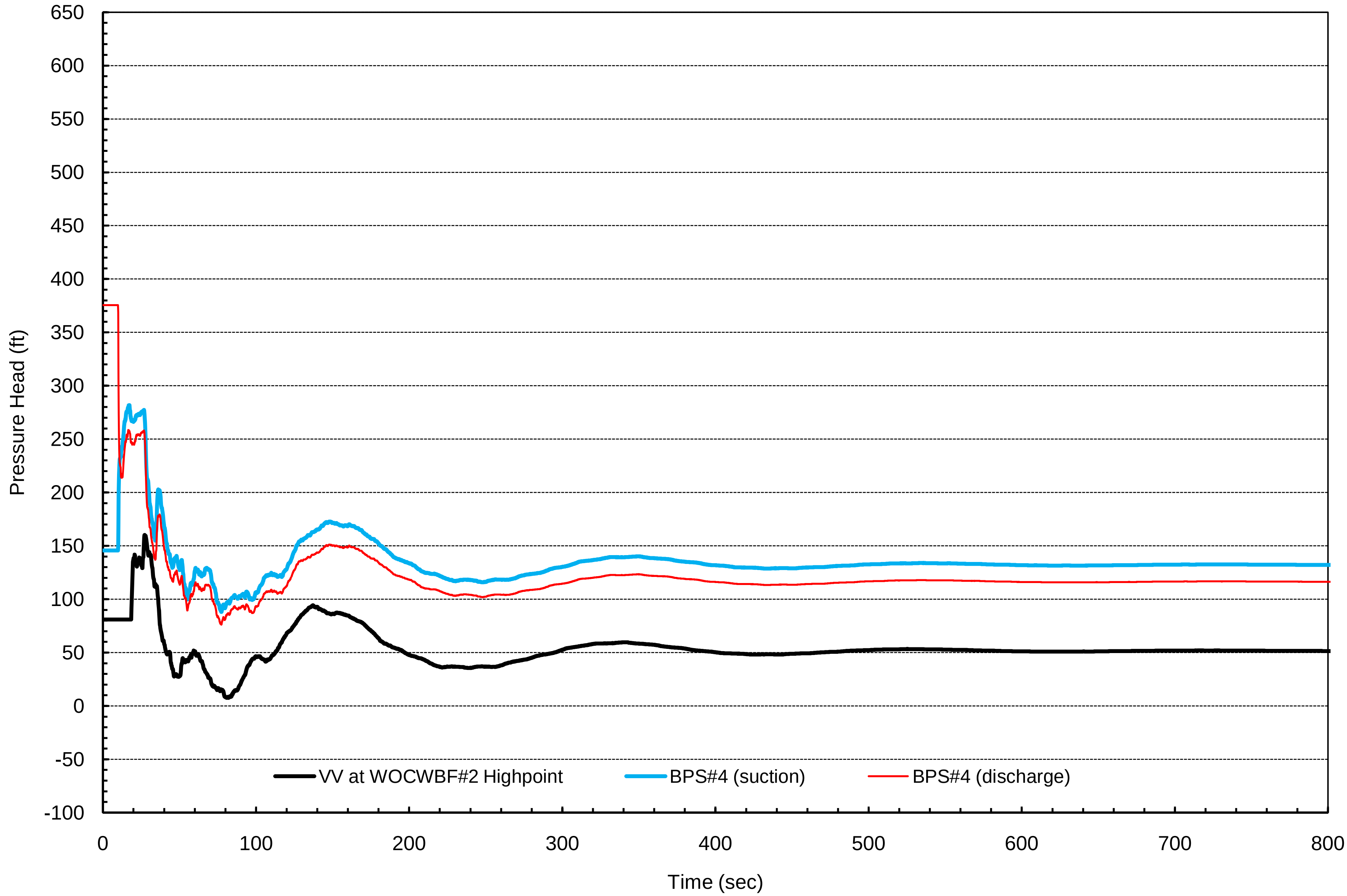

Figure 51: Pressure head records in Path H (WOCWBF#2) following loss of power to booster pump stations under Operating Scenario 3 with surge protection

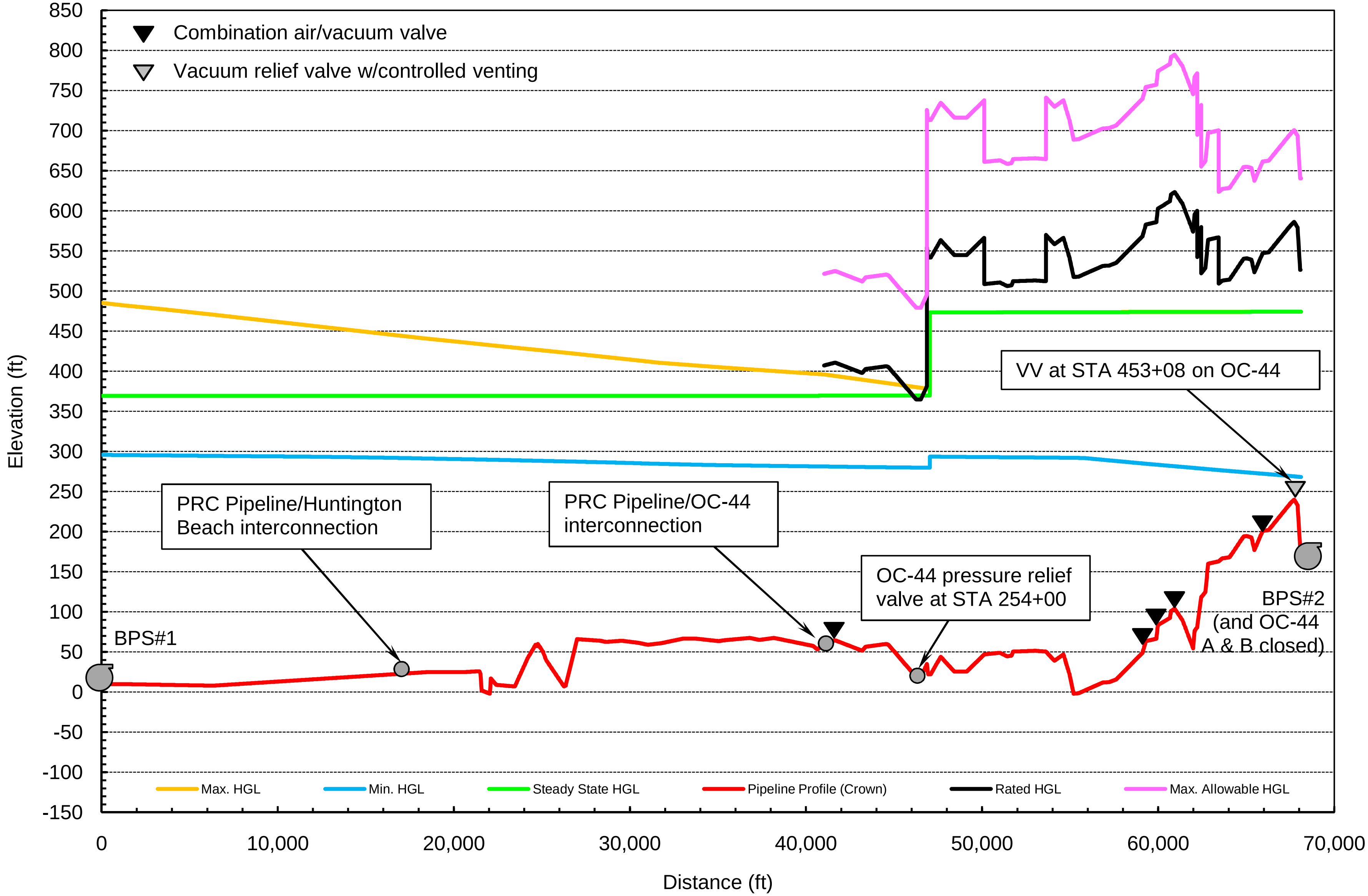

Figure 52: HGL elevations in Path A (PRC Pipeline and OC-44 TM) after startup of the booster pump stations with surge protection

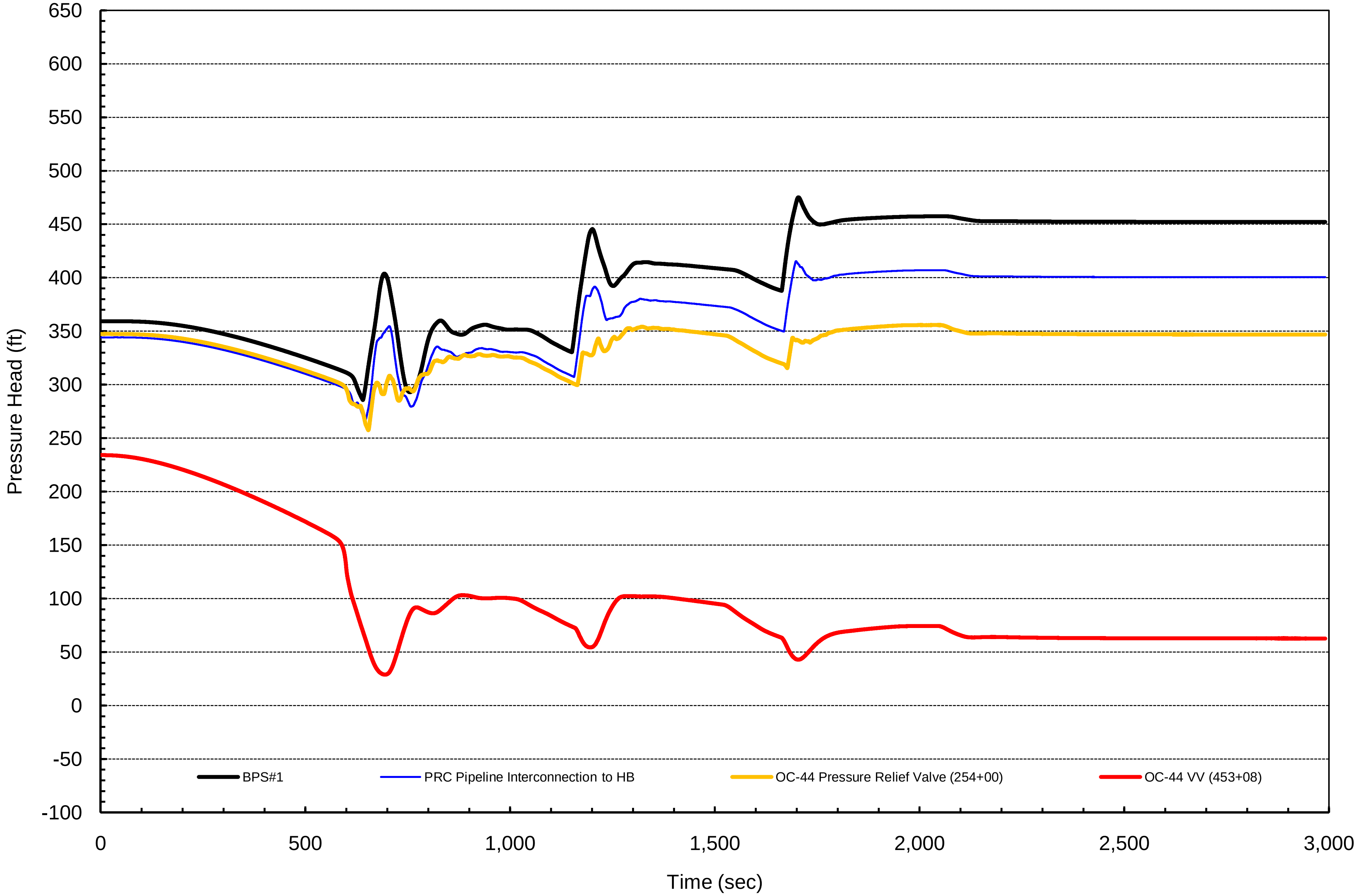

Figure 53: Pressure head records in Path A (PRC Pipeline and OC-44 TM) after startup of the booster pump stations with surge protection

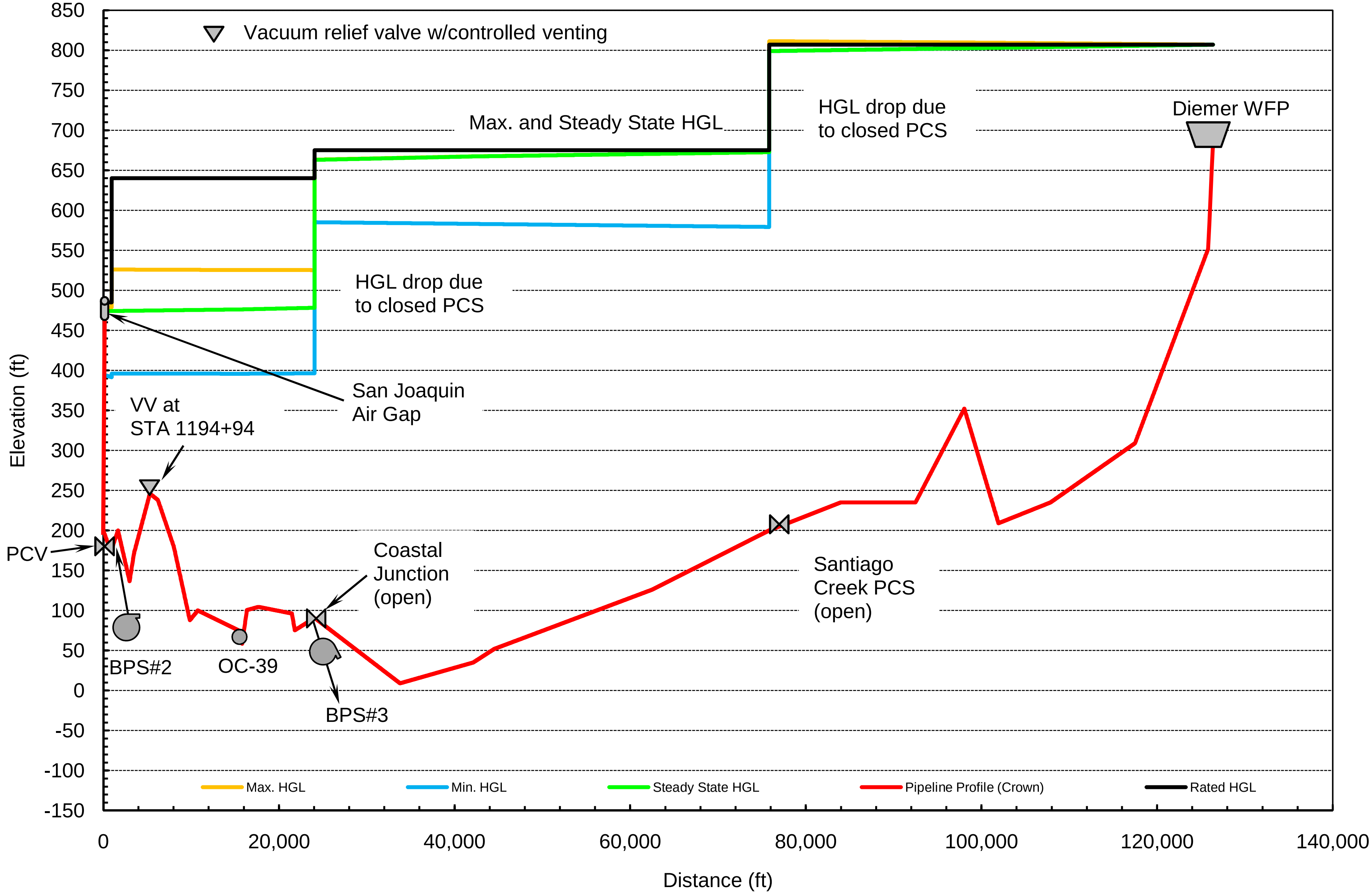

Figure 54: HGL elevations in Path B (EOCF#2) after startup of the booster pump stations with surge protection

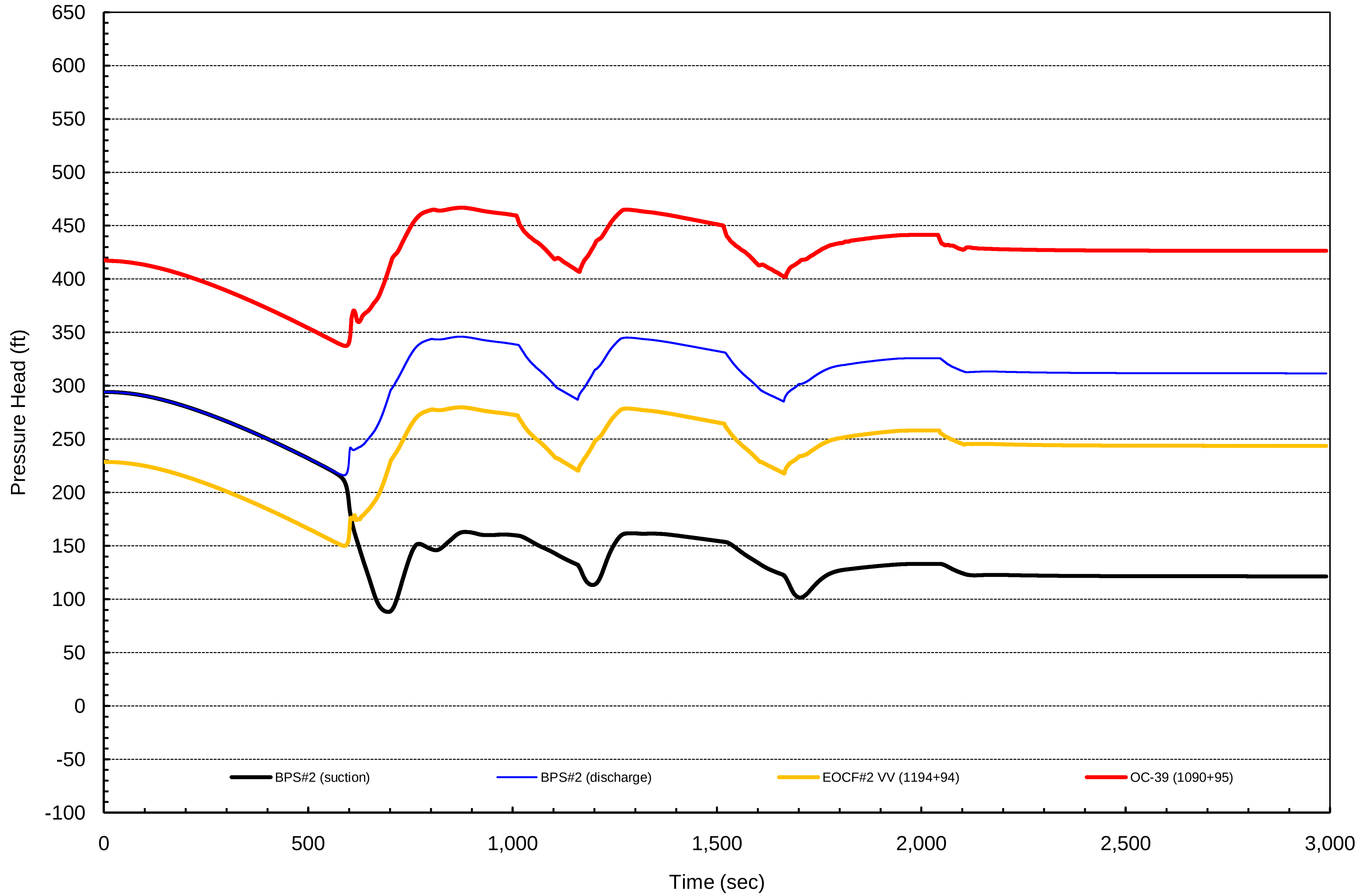

Figure 55: Pressure head records in Path B (EOCF#2) after startup of the booster pump stations with surge protection

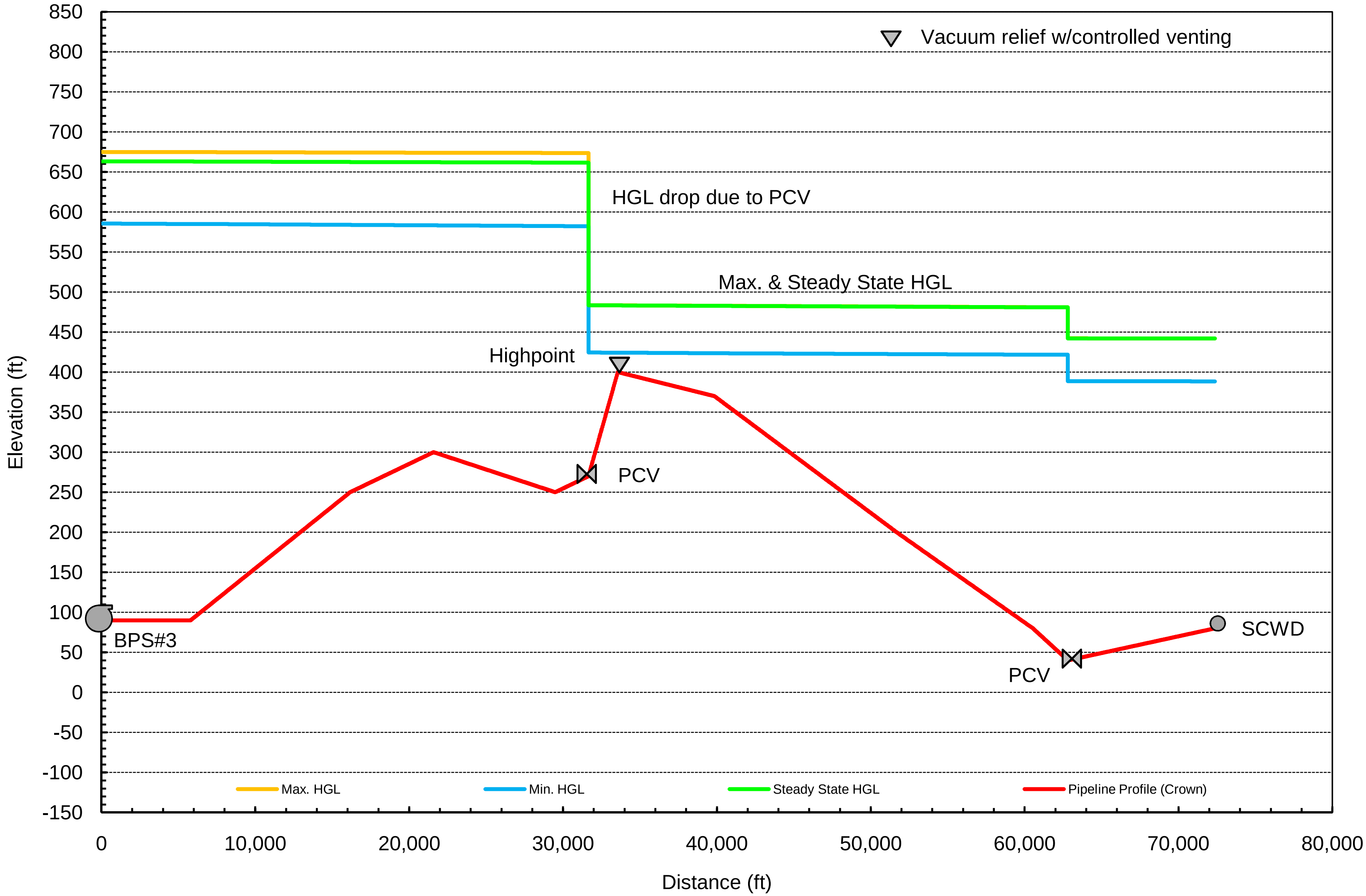

Figure 56: HGL elevations in Path C (Aufdenkamp TM) after startup of the booster pump stations with surge protection

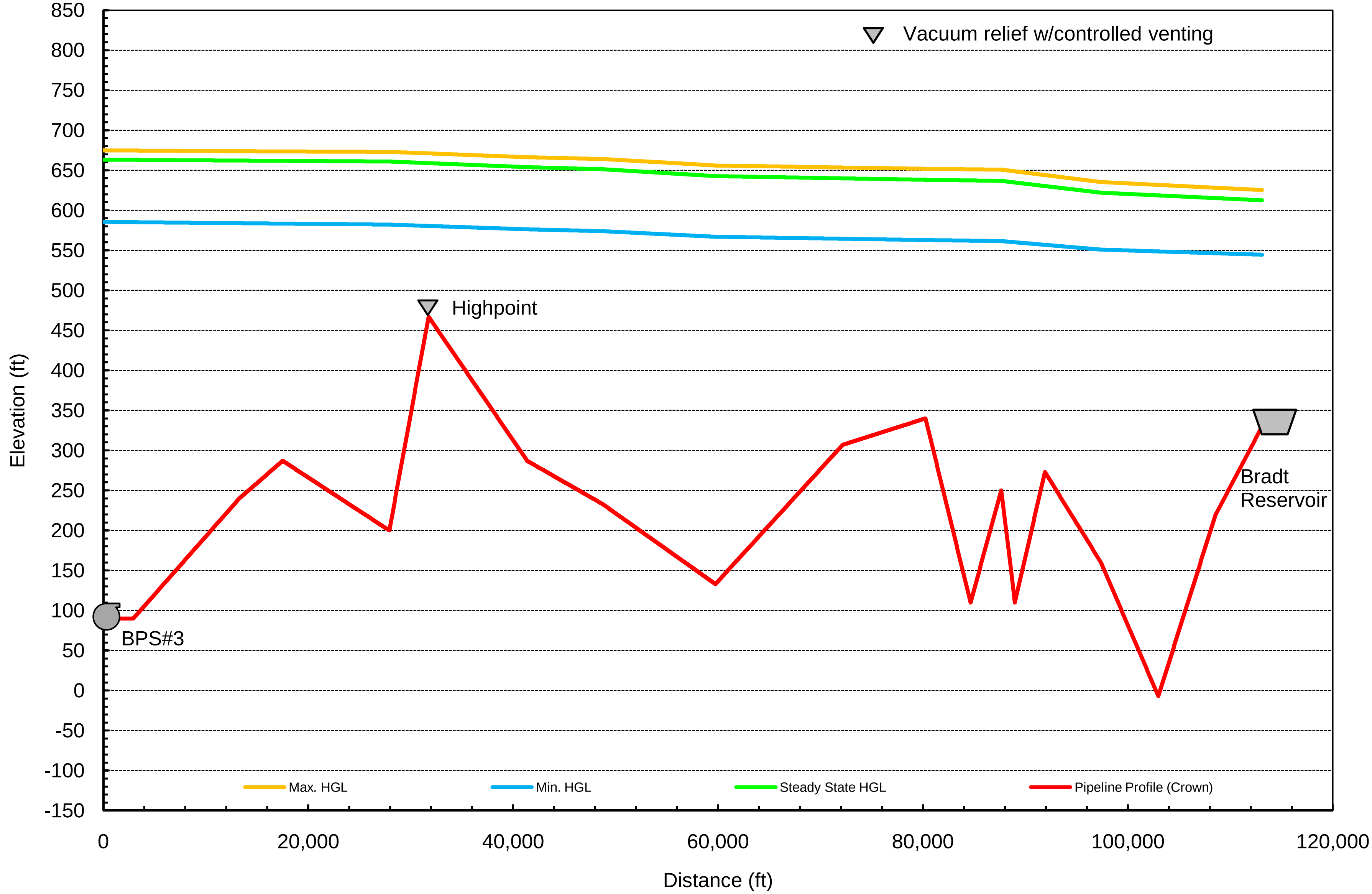

Figure 57: HGL elevations in Path D (Joint TM) after startup of the booster pump stations with surge protection

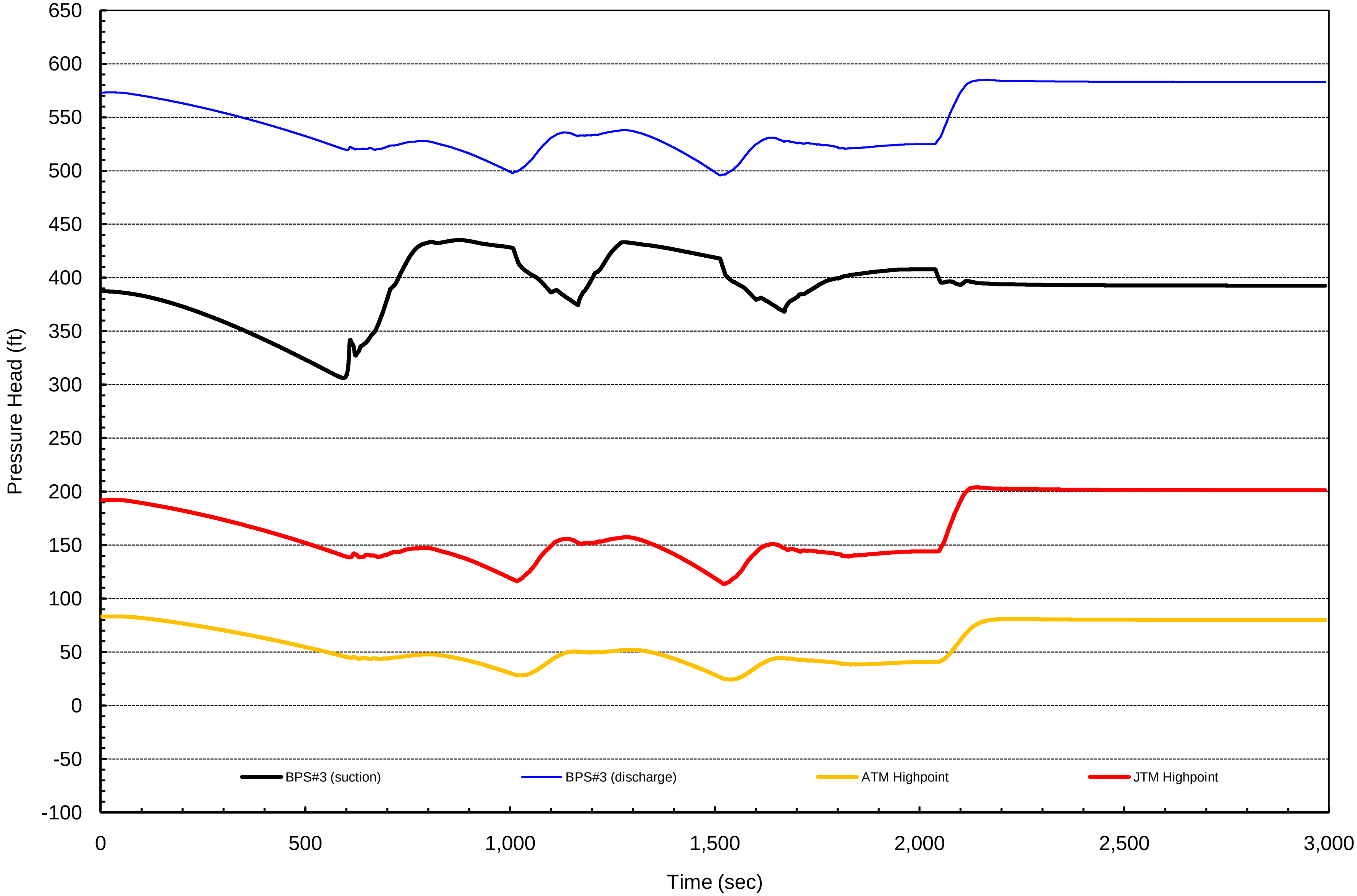

Figure 58: Pressure head records in Paths C and D (Aufdenkamp and Joint TMs) after startup of the booster pump stations with surge protection

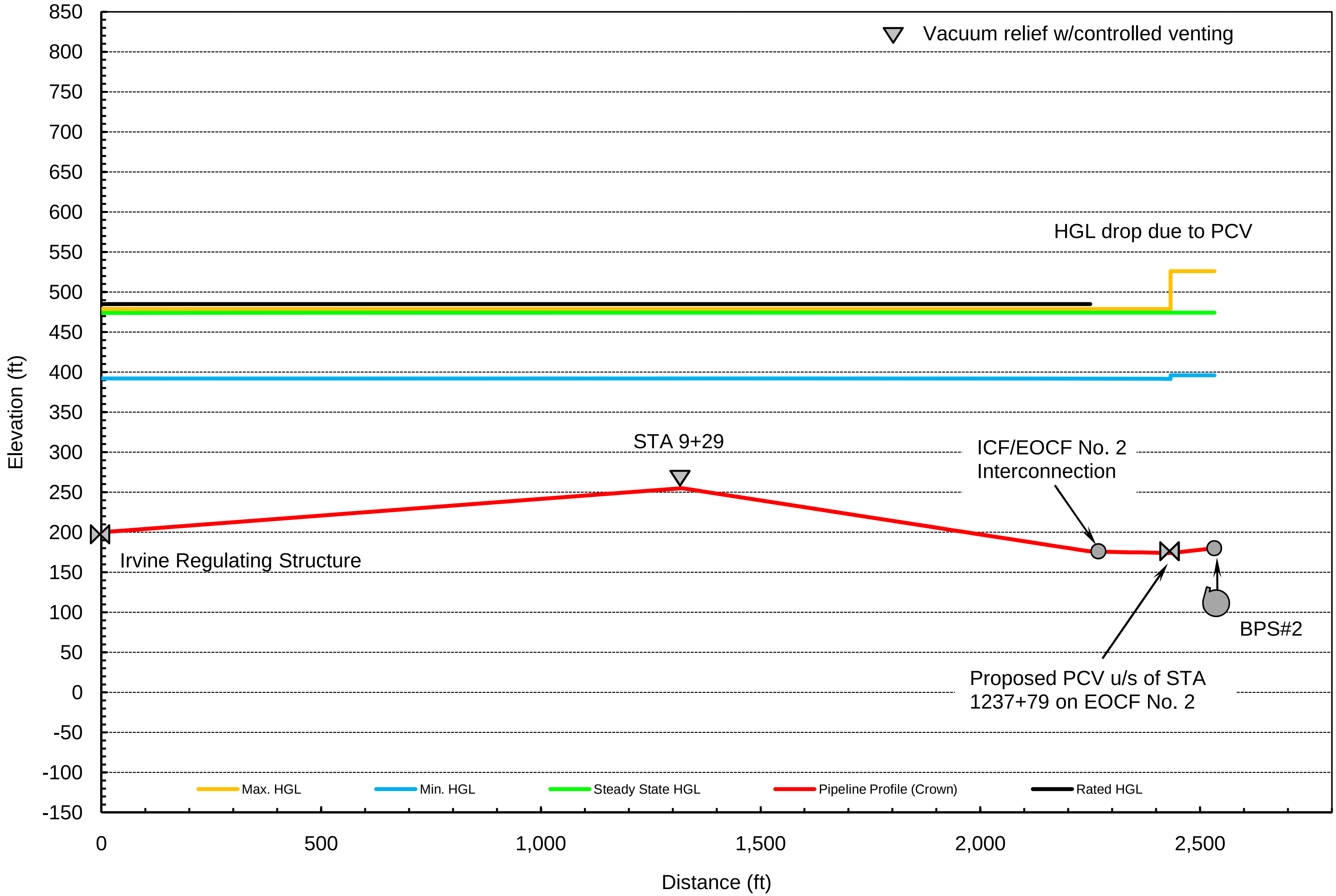

Figure 59: HGL elevations in Path E (Irvine Cross Feeder) after startup of the booster pump stations with surge protection

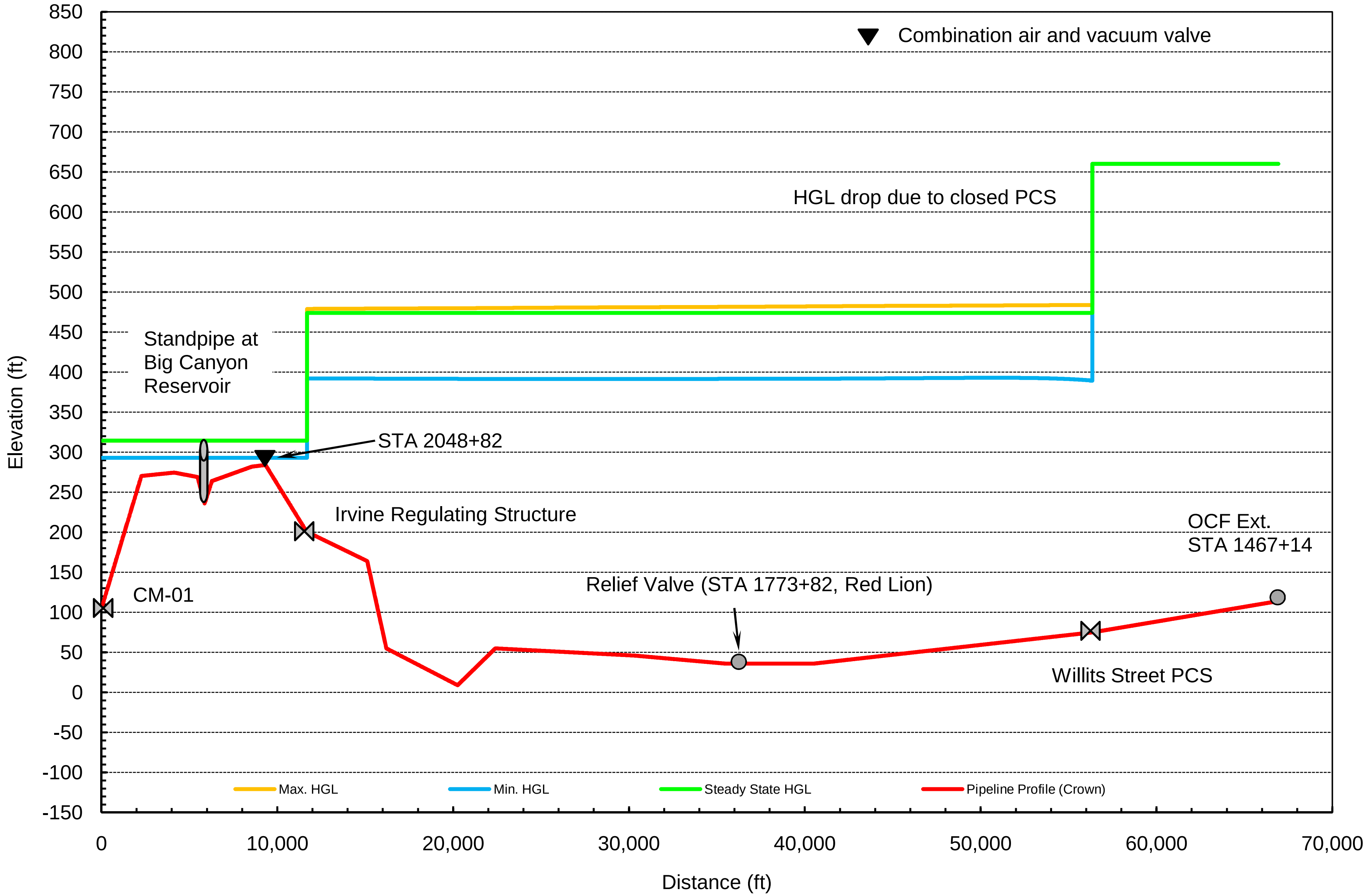

Figure 60: HGL elevations in Path F (OCF Ext.) after startup of the booster pump stations with surge protection

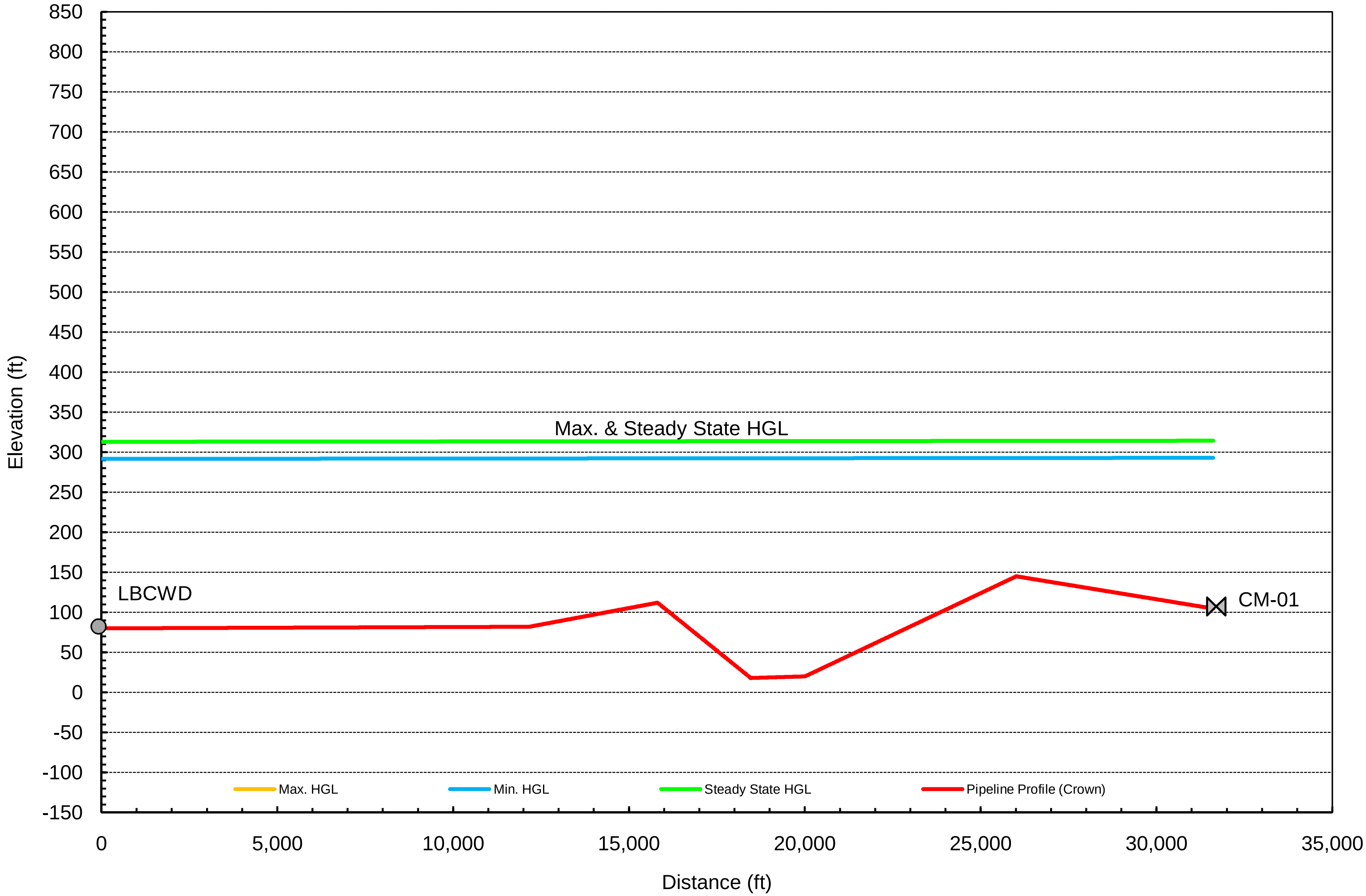

Figure 61: HGL elevations in Path G (Coastal Supply Line) after startup of the booster pump stations with surge protection

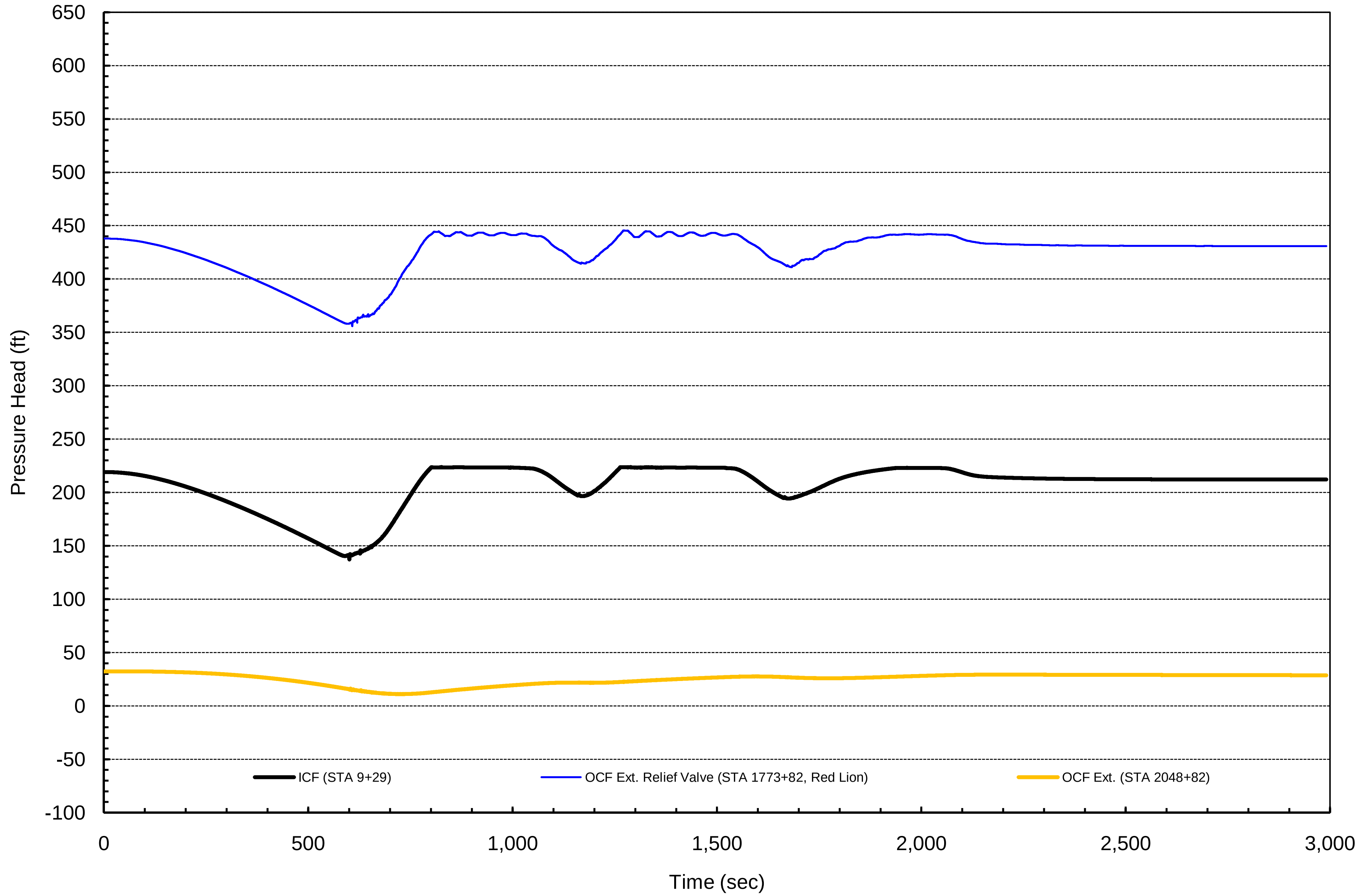

Figure 62: Pressure head records in Paths E and F (ICF and OCF Ext.) after startup of the booster pump stations with surge protection

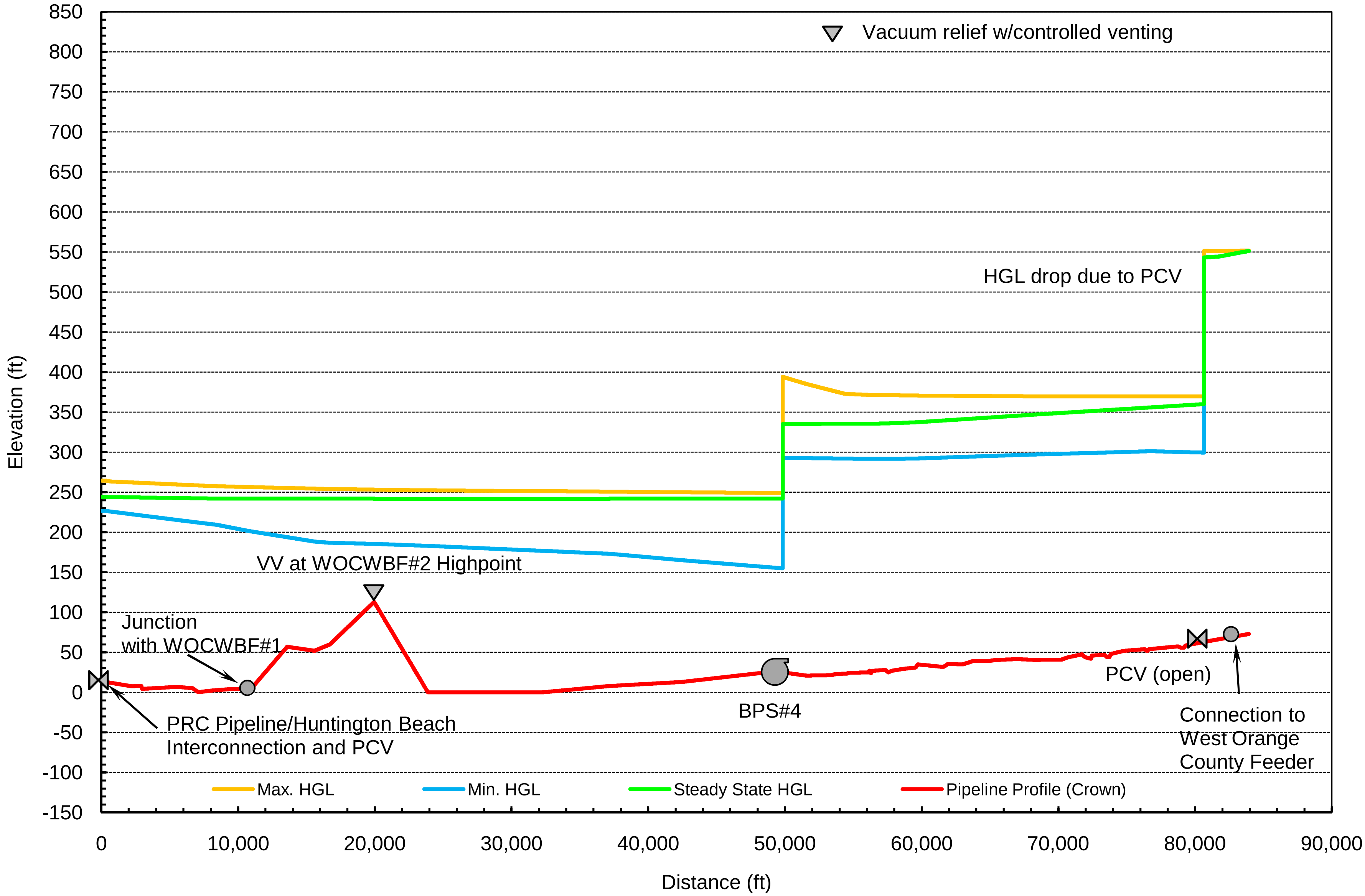

Figure 63: HGL elevations in Path H (WOCWBF#2) after startup of BPS#4 under Operating Scenario 3 with surge protection

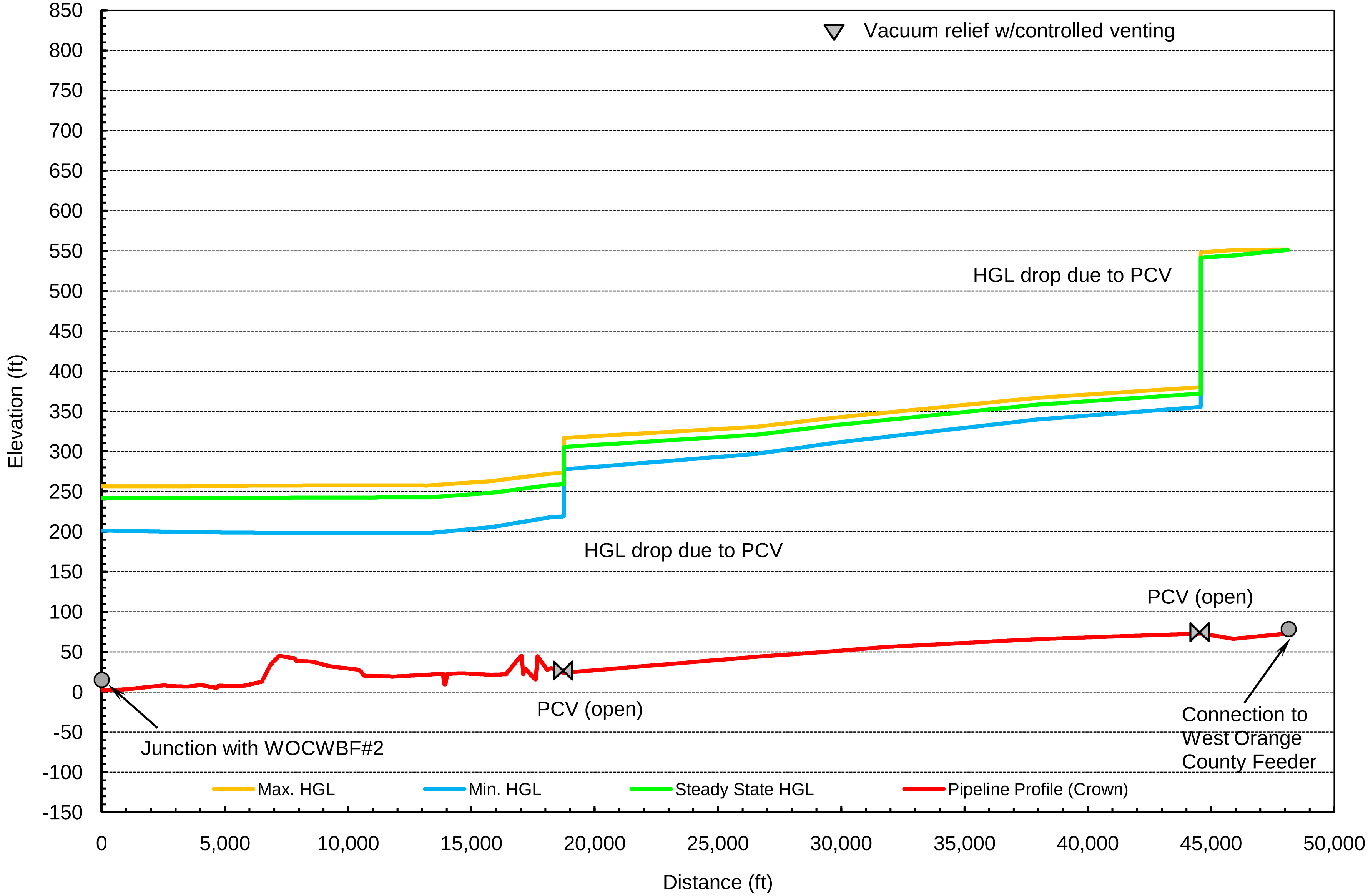

Figure 64: HGL elevations in Path I (WOCWBF#1) after startup of BPS#4 under Operating Scenario 3 with surge protection

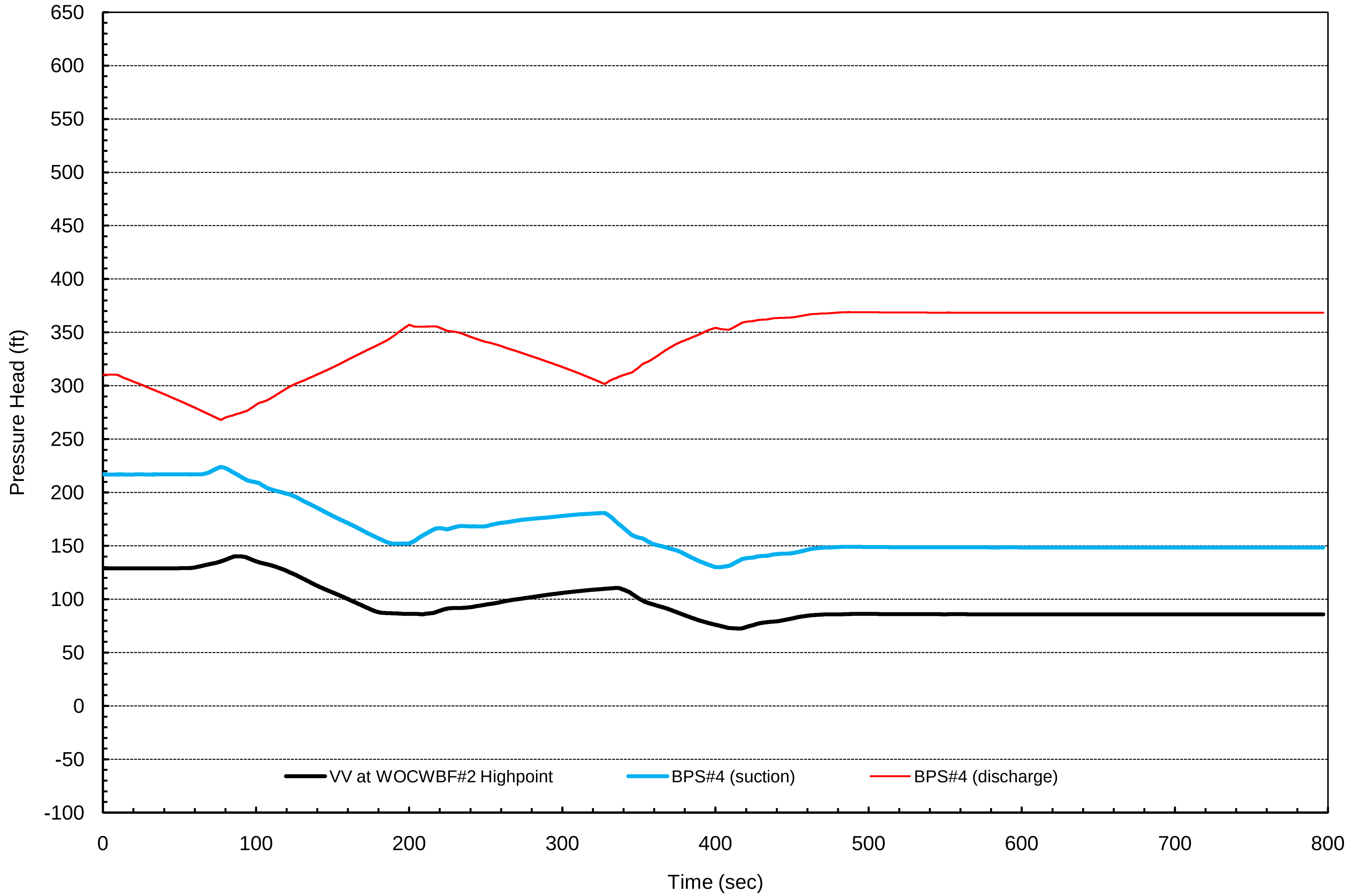

Figure 65: Pressure head records in Path H (WOCWBF#2) after startup of BPS#4 under Operating Scenario 3 with surge protectio

7.0 Conclusions and Recommendations

A pressure surge analysis for Poseidon Resources Corporation's (PRC) proposed Huntington Beach Seawater Desalination Plant and associated product water delivery system has been completed. The product water delivery system includes the proposed 48-inch diameter PRC Pipeline between the plant and the OC-44 Transmission Main, the OC-44 Transmission Main, East Orange County Feeder No. 2 (EOCF#2), the Irvine Cross Feeder (ICF), the Orange County Feeder Extension (OCF Ext.), and the Aufdenkamp, Joint, West Orange County Water Board Feeder No. 1 (WOCWBF#1) and West Orange County Water Board Feeder No. 2 (WOCWBF#2).

Northwest Hydraulic Consultants (NHC) performed power failure and startup analyses for three proposed booster pump stations and one existing booster pump station and recommended surge control measures to protect the booster pump stations and transmission mains from adverse pressure transients resulting from these operations. The results of NHC's analysis show that surge protection is required to eliminate the possibility of vapor cavity formation and collapse in the transmission mains and over-pressurization of the ICF following a loss of power to the booster pump stations at the desalination plant (BPS#1), near the San Joaquin Reservoir (BPS#2), at Coastal Junction (BPS#3) and on WOCWBF#2 in Huntington Beach (BPS#4).

To eliminate the possibility of vapor cavity formation and collapse in the transmission mains and over-pressurization of the ICF, NHC recommends a surge control strategy that involves the installation of pressurized surge tanks at BPS#1 and BPS#2 in combination with the installation of vacuum relief valves with controlled venting features on the transmission mains. The properties of the recommended pressurized surge tanks are summarized in Table C1.

Table C1: Properties of recommended pressurized surge tanks

Properties	***BPS#1 (Discharge)***	***BPS#2 (Suction)***	***BPS#2 (Discharge)***
Tank Volume (ft^3)	2940	3393	1257
Tank Diameter (ft)	12	12	10
Tank Length (ft)	26	30	16
Orifice Diameter (in)	24	24	24
Inlet/Outlet losses (k)	3/3	3/3	3/3
Air Content (%)	30	45	30
Min. Pressure Rating (psi)	250	200	250

A 36-inch diameter bypass pipeline equipped with a check valve that permits flow from the suction to the discharge side of the pump station when the suction pressure exceeds the discharge pressure should be installed at BPS#2.

Although it is not necessary to install a pressurized surge tank on either the suction or discharge sides of BPS#3 and BPS#4 it will be necessary to install additional vacuum relief valves at several locations in the product delivery system. More specifically, it is recommended that vacuum relief valves with controlled venting features (e.g., APCO S-1500C, Valmatic VM-1800VB/38, or equivalent) be installed at the locations in the product water delivery system shown in Table 4 of this report, which also lists the recommended minimum diameter for the vacuum relief valves. Alternatively, slow closing air/vacuum valves (e.g., APCO Series 1700, or equivalent) or single-body vacuum relief valves (e.g., Vent-O-Mat RBXb) equipped with a bias mechanism could be installed. Note that the static pressure at each location should be carefully compared to the required minimum seating pressure before selecting single body vacuum relief valves. The vacuum relief valves should be duplicated to provide redundancy in case a valve fails to open, opens too slowly, or is removed for service. Regular maintenance should be performed on the vacuum relief valves to ensure that they are always in good working order.

Some of the locations listed in Table 4 may already be equipped with combination air and vacuum relief valves for filling and draining. If equivalent or larger diameter vacuum relief valves than those recommended in Table 4 are already installed, additional vacuum relief valves need not be installed at these locations.

It may be possible to slightly reduce the volume of the recommended pressurized surge tank on the suction side of BPS#2 by installing a surge relief valve equipped with an anticipatory feature on the suction side of the booster pump station. However, the surge relief valve would potentially discharge a significant quantity of treated water to waste that would have to be de-chlorinated prior to disposal. Additional pressure surge analyses would be required to size the surge relief valve and re-size the surge tank.

A booster pump station startup analysis presented in this report shows that switching the water delivery system from MWD water to desalination plant product water without interrupting the water supply to customers is hydraulically feasible. In order to switch the supply from MWD water to desalination plant product water it is recommended that the pumps at the booster pump stations be ramped up to full speed in 200 seconds or longer. The pumps at BPS#1, BPS#2, and BPS#3 should be started one at a time with at least a 500 second lag between each pump start. The pumps at BPS#4 should also be started one at a time, but only a 200 second lag between each pump start is required. The pumps at each booster pump station can be started in any order. Approximate opening and closing times for the pressure and flow control facilities in the product delivery system are described in Section 6 of this report.

Future Pressure Surge Analysis Required

This pressure surge analysis was performed at a preliminary planning stage of the Huntington Beach Seawater Desalination Plant Project. Therefore, it is important to note that both the results of the pressure surge analysis and the recommended surge control measures for the booster pump stations and product water delivery system that are presented in this report should be checked and, if necessary, updated as the designs for the booster pump stations are more fully developed. This is because the recommendations provided in this report are somewhat sensitive to the selected pumps and valves, which have yet to be finalized.

Necessary Upgrades to the Product Water Delivery System

The following hydraulic upgrades, which are unrelated to surge control, should be made to the transmission mains to facilitate delivery of the desalination plant product water.

4. A 42-inch diameter bypass equipped with a hydraulically operated isolation valve (e.g., ball, plug or cone valve) should be installed at the existing pressure control structure located at STA 254+00 on the OC-44 Transmission Main. The bypass will permit the pumping of product water around the pressure control structure, which will be closed at the time. The pressure control structure will be open and the isolation valve will be closed when, as is currently the case, MWD water is supplied to the OC-44 Transmission Main.

5. A pressure control valve should be installed near STA 1237+79 on EOCF#2, which is upstream of the connection to the ICF. The pressure control valve should be set to maintain a downstream hydraulic grade line elevation that is less than 478 ft, which will prevent over-pressurization of the ICF and spillage of product water to the San Joaquin Reservoir when BPS#2 is operating.

6. The existing pressure relief valve at STA 1090+95 on EOCF#2, which is currently set to open at an HGL elevation of approximately 485 ft, should be locked out when BPS#2 is operating. This will prevent the pressure relief valve from opening, which is not required when product water is supplied to the delivery system.

Previous Pressure Surge Analysis Work

Note that a pressure surge analysis previously performed by Dr. Axworthy (who is also an author of this report) in 2005 did not include WOCWBF#1 and WOCWBF#2 in Huntington Beach or BPS#4. Furthermore, the PRC proposed total dynamic head (TDH) for BPS#2 has been significantly reduced since the 2005 surge analysis was performed. For these reasons, this report supersedes all the work presented in the 2005 surge analysis.

8.0 Appendix A – Movies

The enclosed CDROM contains movies of HGL elevation animations for pump power failure and pump startup at the booster pump stations. The movie files can be viewed with Microsoft Corporation's Windows Media Player© or other comparable software.

Table A1: Movie filenames and figure numbers

Filename	*Description*	*Figure #*
S1PathA-pf.avi	Scenario 1, Path A, Power Failure, w/o Protection	2
S1PathB-pf.avi	Scenario 1, Path B, Power Failure, w/o Protection	4
S1PathC-pf.avi	Scenario 1, Path C, Power Failure, w/o Protection	6
S1PathE-pf.avi	Scenario 1, Path E, Power Failure, w/o Protection	9
S1PathA-pf-wp.avi	Scenario 1, Path A, Power Failure, w/Protection	13
S1PathB-pf-wp.avi	Scenario 1, Path B, Power Failure, w/Protection	15
S1PathC-pf-wp.avi	Scenario 1, Path C, Power Failure, w/Protection	17
S1PathE-pf-wp.avi	Scenario 1, Path E, Power Failure, w/Protection	20
S2PathH-pf-wp.avi	Scenario 2, Path H, Power Failure, w/Protection	35
S2PathI-pf-wp.avi	Scenario 2, Path I, Power Failure, w/Protection	36
S3PathH-pf-wp.avi	Scenario 3, Path H, Power Failure, w/Protection	49
S3PathI-pf-wp.avi	Scenario 3, Path I, Power Failure, w/Protection	50
S1PathA-s-wp.avi	Scenario 1, Path A, Startup, w/Protection	52
S1PathB-s-wp.avi	Scenario 1, Path B, Startup, w/Protection	54
S1PathC-s-wp.avi	Scenario 1, Path C, Startup, w/Protection	56
S1PathE-s-wp.avi	Scenario 1, Path E, Startup, w/Protection	59
S3PathH-s-wp.avi	Scenario 3, Path H, Startup, w/Protection	63
S3PathI-s-wp.avi	Scenario 3, Path I, Startup, w/Protection	64

9.0 Appendix B – Maximum and Minimum Pressures

The predicted maximum and minimum pressures in the product water delivery system with surge control installed are provided in Table B1.

Table B1: Predicted maximum and minimum pressures in the delivery system

Location	*Pressures (psi)*	
	Maximum	*Minimum*
Huntington Beach Desalination Plant (BPS#1)	206	43
PRC Pipeline and OC-44 TM Interconnection	147	56
OC-44 (STA 254+10) Pressure Relief Valve	177	78
OC-44 (STA 453+08) Vacuum Relief Valve	117	-1
BPS#2 Suction	145	22
BPS#2 Discharge	150	26
Irvine Cross Feeder	131	0
OC-63/OC-57 Turn Out on EOCF#2	152	71
OC-39 Turn Out on EOCF#2	238	80
BPS#3 Suction	243	49
BPS#3 Discharge (Coastal Junction)	253	123
SCWD (Aufdenkamp Transmission Main)	154	106
Red Lion Pressure Relief Valve (STA 1773+82 on OCF Ext.)	190	93
CM-01 (Coastal Supply Line)	90	81
BPS#4 Suction	119	39
BPS#4 Discharge	163	33
PRC Pipeline and Huntington Beach OC-44 TM Interconnection	180	56

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nhc
northwest hydraulic consultants

April 22, 2010

Poseidon Resources Corporation
17011 Beach Blvd., Suite 900
Huntington Beach, CA 92647

Attention: **Ms. Josie McKinley**

Subject: **Huntington Beach Seawater Desalination Plant Pressure Surge Analysis**

Dear Ms. McKinley:

As you know, Northwest Hydraulic Consultants (NHC) recently completed a pressure surge analysis for the Huntington Beach Seawater Desalination Plant and product water delivery system on behalf of Poseidon Resources Corporation (PRC). After the surge analysis was completed two modifications were made to the steady state analysis of the proposed delivery system by PRC's modelers, IDModeling. This letter reviews these modifications and their potential impact on the results of NHC's recently completed pressure surge analysis.

First, the capacity for the pump proposed for installation at the fourth booster pump station (i.e., BPS#4 in the NHC report) in the product water delivery system has been reduced by approximately 30 percent. BPS#4 discharges to West Orange County Water Board Feeder No. 2 (WOCWBF#2) and is proposed to operate only under Scenario No. 3, which is defined in the surge analysis report. Since the flow rate has been reduced significantly, the pressure transients created by a loss of power or startup of this pump will be smaller in magnitude than those illustrated in NHC's pressure surge analysis report. Therefore, surge control, in addition to that recommended in the surge analysis report for WOCWBF#2, should not be necessary at BPS#4 to accommodate this flow rate modification.

The second change to the steady state analysis involved reducing the total dynamic head (TDH) at the third booster pump station (i.e., BPS#3 in the NHC report) and IDModeling should be consulted for more information on this modification. BPS#3 will be installed near Coastal Junction and a lower TDH means that pumps and motors with less polar moment of inertia than was assumed for the surge analysis will be selected. Although a lower moment of inertia means that the transients created by BPS#3 following pump power failure or startup will be less attenuated, a preliminary sensitivity analysis showed that the pressure transients created in the Aufdenkamp and Joint Transmission Mains as well as in East Orange County Feeder No. 2 (EOCF#2) by the modified pump station will be no worse than those illustrated in our surge analysis report for these pipelines. Therefore, the surge control measures recommended in NHC's report should be satisfactory for the modified design of this pump station.

Please note that the above modifications to the system affect all of the transient analysis scenarios presented in NHC's pressure surge analysis report. Therefore, we strongly recommend that the surge analysis be re-performed at a later date once the system facilities are more well defined so that the recommended surge control measures can be checked and, if necessary, revised to be compatible with the modified system.

If you have any questions or need further information, please do not hesitate to me at (626) 440-0080 or by email at dAxworthy@nhcweb.com.

Yours truly,
Northwest Hydraulic Consultants, Inc.

David H. Axworthy, Ph.D., P.E.
Associate